

Cruise report: R/V G.O.Sars July 17-30, 2013

Cruise 2013109, along 75°N and 74.5°N

Cruise leader: Siv K. Lauvset

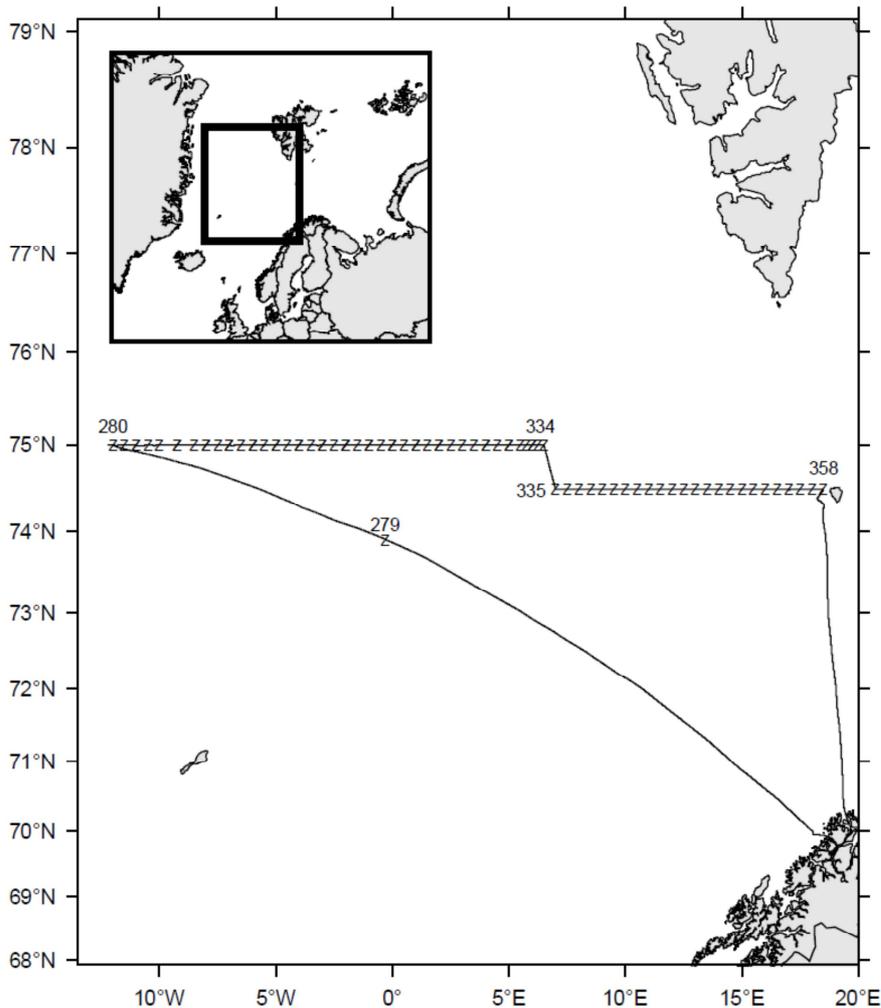
Cruise objective:

This was a carbon chemistry cruise along a CLIVAR repeat section at 75°N. This section, and the Bjørnøya West section along 74.5°N (Figure 1) has been sampled every 3-4 years. The 2013 cruise was financed by the EU project CARBOCHANGE. The overall goal was to measure the major ocean carbon chemistry variables (dissolved inorganic carbon and alkalinity), in order to quantify temporal changes in these. These data are important for a variety of purposes:

- 1) Quantifying the size of the ocean carbon sink and changes in this
- 2) Research on deep water formation and ocean ventilation
- 3) Ocean acidification research

The main tasks of the cruise were to:

- 1) Take samples for dissolved inorganic carbon, alkalinity, oxygen, and trace gases (CFCs and SF6) and analyze these onboard
- 2) Take samples for C-13, C-14, and nutrients to be analyzed on land.
- 3) Take underway measurements of pCO₂, pH, and O₂/Ar



Cruise no 2013109
 "G.O.Sars"
 17–30 July 2013
 z CTD st.no 279–358

Figure 1. Map of the cruise transect. Z indicates a CTD station.

Cruise narrative:

July 17, 2013

We left Tromsø harbor at 12:30 to take on fuel and freshwater. We headed out to sea at 17:00. Mirjam Glessmer was chosen to be the responsible person for the chemicals. Tor de Lange is the health and safety representative for the scientific crew.

Transit to the first station is expected to be approximately 60 hours. Underway we will stop once to do a test station. There we will test the CTD sensors and train people on correct sampling procedures.

July 19, 2013

I made the decision to postpone the first station by four (4) hours until 0800 tomorrow July 20, 2013. This gives Emil Jeansson more time to get the tracer instrumentation up and running.

July 22, 2013

The DIC and alkalinity instruments are still the only ones running. We will prepare for running the pH instrument also since we have enough people to keep an eye on it.

July 23, 2013

Both ARGO floats from the Finnish Meteorological Institute were successfully deployed – one at 75°N 3°W and the other at 75°N 2°W. Note that it took ~25 minutes for the bladder to fully inflate, not 10 minutes as per the instructions. The second float had to be manually started (using the COM-port).

July 23, 2013

Mirjam Glessmer has started to pack up the Winkler O₂ system. If we can figure out the problems we will set it up again.

July 24, 2013

First sampling for trace gases.

Marie Eide has started post-processing the DIC and alkalinity data, i.e. correcting to “true” CRM values and correcting for drift between CRM runs.

I have slowed our cruising speed between stations to 6 knots to allow Emil Jeansson more time to get the tracer instrument up and running. We will speed up again when we get to 74.5°N.

Our new ETA back in Tromsø is sometime before 1600 on July 29, 2013. This is so that a winch on board can be repaired before the next cruise.

July 25, 2013

We have decided to take oxygen samples from three stations and bring these back to Tromsø where Mirjam Glessmer will analyze them at the Norwegian Polar Institute.

July 26, 2013

Today the alkalinity instrument had to sit idle for ~30 minutes while waiting for samples to finish running on the DIC instrument.

July 27, 2013

We slowed our cruising speed between stations in order to catch up on analyzing samples for DIC and alkalinity.

July 28, 2013

The last station was at 0100 today and all samples for DIC and alkalinity were finished by 0700. ETA in Tromsø is early tomorrow morning (i.e. around breakfast time).

Final notes:

The DIC and alkalinity instrumentation have worked very well.

We could not get the tracer instrument running, and we were not able to analyze for oxygen.

The CTD salinities from 2013 are very different from those in 2006 and 2009. Hopefully this is a sensor calibration issue that will resolve itself. Still, it is a pity that we do not have some complete profiles of bottle salinities.

Measurements made onboard:

Dissolved inorganic carbon (DIC), alkalinity, dissolved oxygen, and trace gases (CFCs and SF₆).

CTD measurements

Responsible: Siv K. Lauvset, Vidar Lien

The CTD used on this cruise is a Sea-Bird SBE 9 with dual sensors for temperature and conductivity. The CTD also has an oxygen sensor. At each position two salinity samples were taken and brought back to shore for analysis. These bottle salinities were then used to calibrate the CTD salinities. The salinity samples were always taken from the deepest niskin bottle and from a bottle closed in the range 500-1000 m. Figure 2 shows one salinity profile from the Greenland Sea along with the difference between the two sensors – both before calibration. The primary sensor is the one that is regularly calibrated (the secondary sensor is never calibrated using bottle salinities). Figure 3 shows the same salinity profile as Figure 2 after the primary sensor has been calibrated.

The calibration factor for CTD salinity on this cruise is -0.002 . This is an average of the difference between the bottle salinity and the CTD salinity – outliers removed – for the entire cruise. No pressure dependency can be confirmed for this cruise, though the difference between bottle and CTD salinities is larger for samples taken deeper than 2000 m than it is for samples taken shallower than 550 m. Vidar Lien at IMR who did the calibration says he found pressure dependencies on cruises onboard GOSars in 2008 and 2009. It is not yet known whether the CTD sensors have been changed and/or maintained after that.

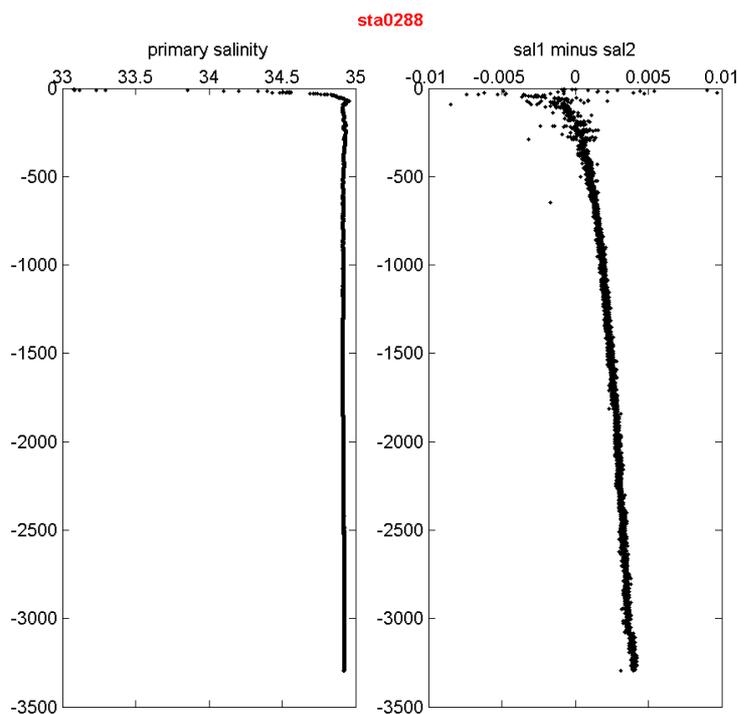


Figure 2. This figure shows CTD salinity from station 288 (75°N, 8.5°W). On the left is the profile from the primary sensor on the CTD and on the right is the difference between the primary and secondary sensor.

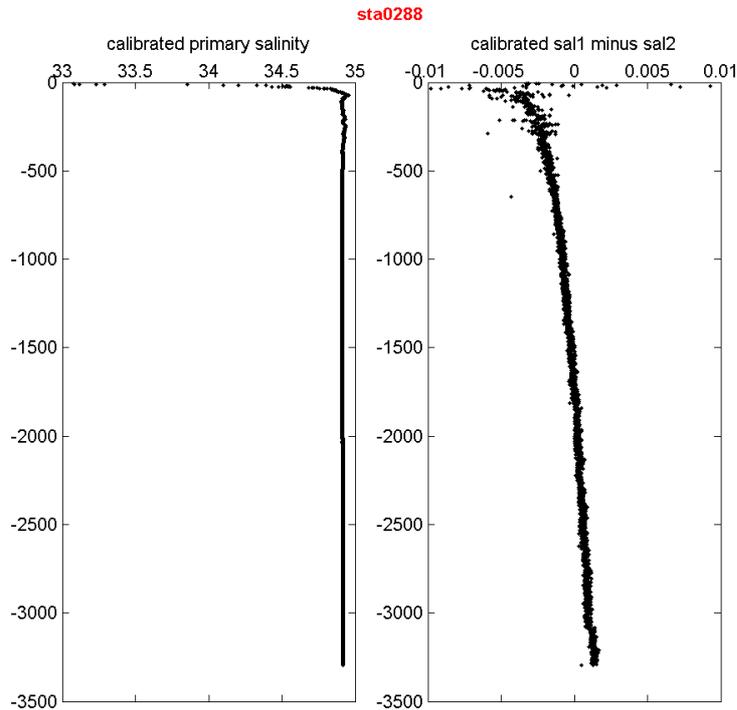


Figure 3. This figure shows the same CTD salinity profile as Figure 2, but after sensor 1 has been calibrated.

The crossover results for CTD salinity (Figure 4) shows a significant offset with respect to recent reference cruises even when accounting for the expected temporal trend.

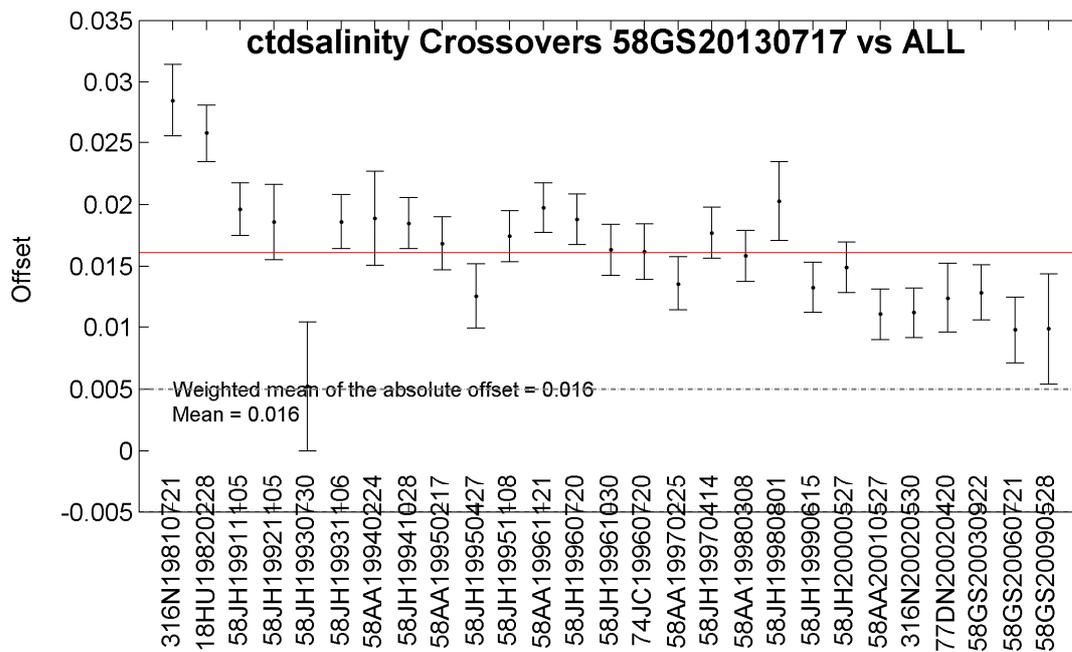


Figure 4. Crossover results for ctd salinity. The reference is always bottle salinity.

The offset seems to be even larger in the intermediate water (Figure 5) so the CTD salinity data were also compared with salinity profiles taken from the two ARGO floats that were deployed during the cruise (Figure 6). There is a significant offset with the GOSars data being higher than the ARGO data.

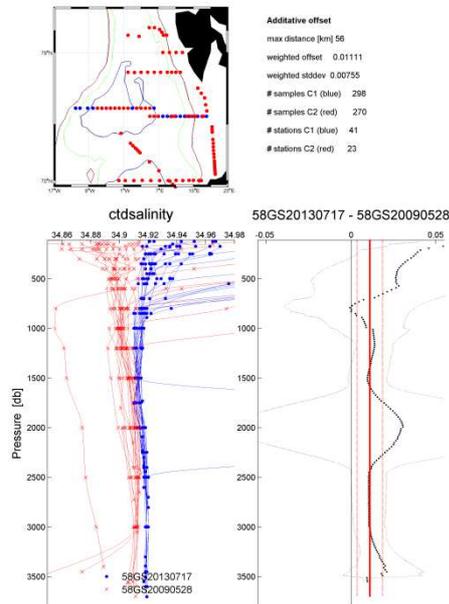


Figure 5. Crossover result between this cruise and the most recent previous occupation of the 75°N transect (58GS20090528) showing all data below 100 m.

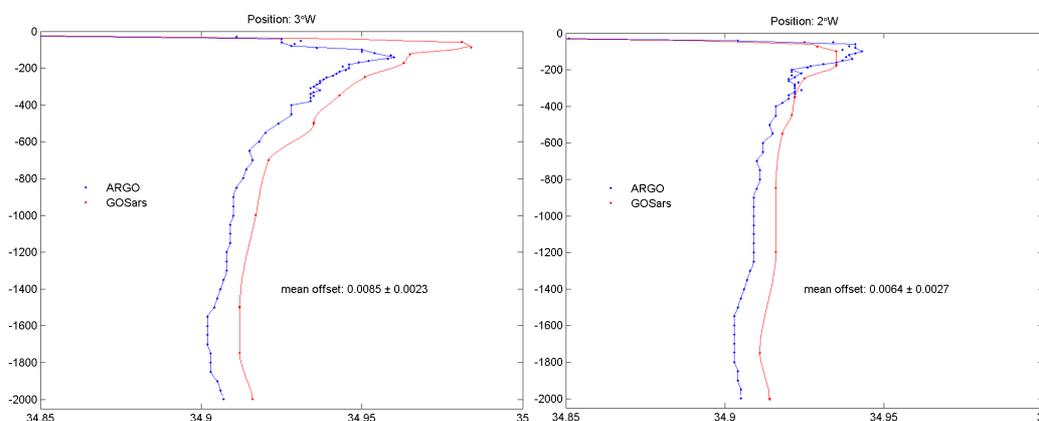


Figure 6. Figure showing the comparison between CTD salinity from G.O.Sars (red) and salinity from the ARGO floats that were deployed during the cruise (blue).

Based on our comparison of the CTD salinity measured by GOSars in 2013 with salinities from GOSars in other years, as well as the ARGO profiles, the CTD salinities from the 2013 cruise are most likely too high. There is, however, not enough evidence to determine what the exact offset is. No corrections beyond the -0.002 difference from bottle salinities have been applied to the data.

No samples could be analysed with Winkler in order to calibrate the CTD oxygen sensor. The accuracy of the oxygen values from the CTD sensor was therefore analysed using a crossover

method. We know that there is a trend of increasing oxygen in the deep Greenland Sea, but even accounting for this the results from the crossover analyses for different depth levels show a consistent 10% low bias in the CTD oxygen values from this cruise (Figure 7).

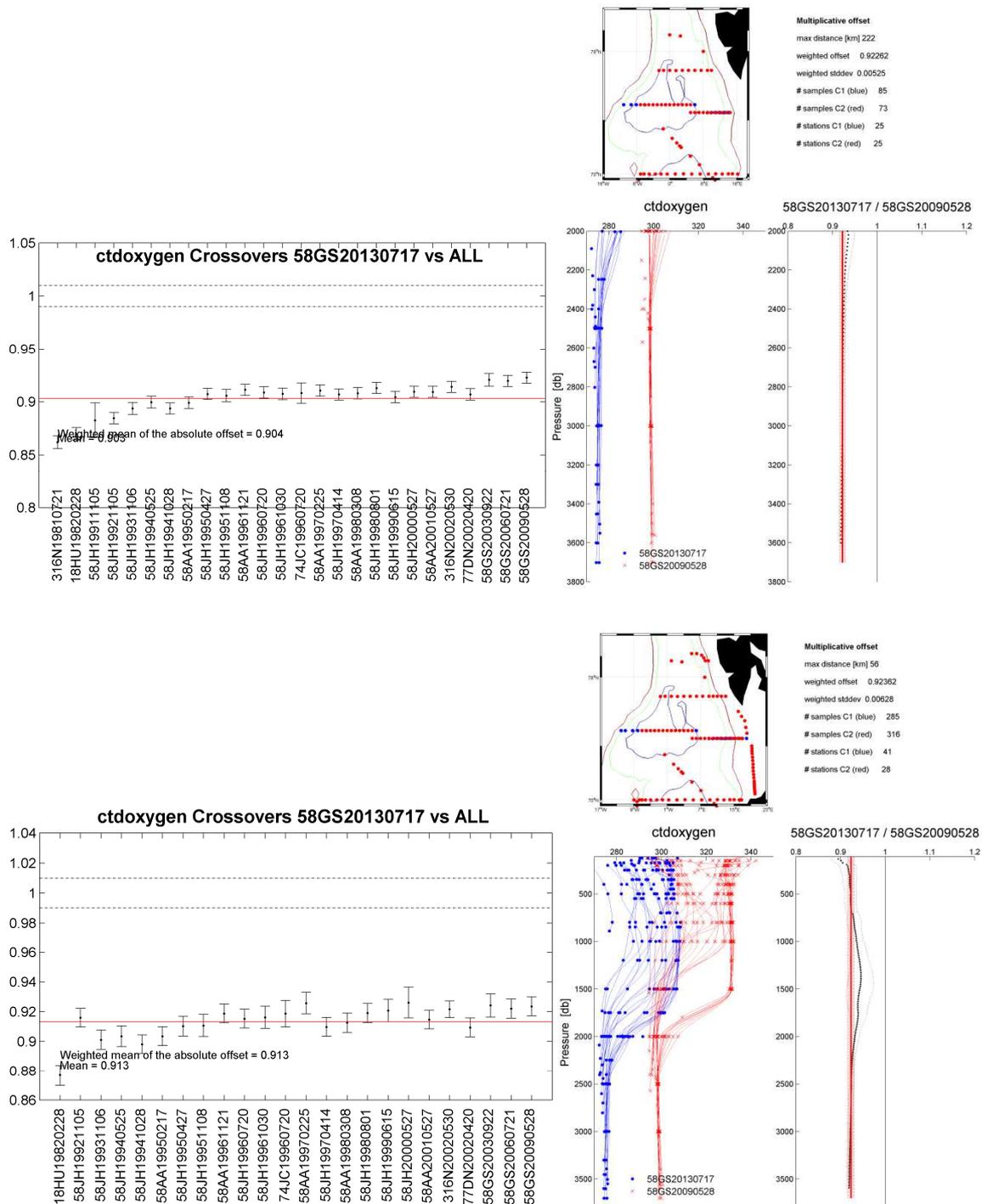


Figure 7. Results of the crossover analysis of CTD oxygen. On top are the results for stations deeper than 1900 m and on bottom the results for all stations deeper than 100 m. On the right hand side are the comparison of this year's CTD oxygen data (blue) with Winkler oxygen data from the same transect in 2009 (red).

Dissolved inorganic carbon and alkalinity

Responsible: Siv K. Lauvset

DIC

- We analyzed for DIC (Figure 8) using a coulometric method, using a VINDTA CT instrument from Marianda. This generally worked very well for the entire cruise. The blank was 91.7 for the entire cruise and the titration generally finished in 8-12 minutes.
- The peltier cooler was frozen the first day but everything worked fine again when it was thawed.
- It appears that sometimes the pipette was not properly filled. This resulted in very low DIC values. These have been flagged 3 in the data file. Unfortunately this was never observed directly, only after the fact by there being very little water in the stripper and the results being very low.
- CRMs were run before and after each position. This means that for the 75°N transect when we did two casts on most chemistry positions there are two stations between the CRMs (19 bottles) whereas for most of the 74.5°N transect when we did only one cast on the chemistry positions there is one station between the CRMs (12/13 bottles). The accuracy on the CRM values was approximately $-10 \mu\text{mol kg}^{-1}$ – slightly less for the first few stations.
- Duplicates:
 - On the 75°N transect two niskin bottles were closed at the same depth (or within 10 m of each other) and we used these as duplicates. The depth was varied from station to station.
 - On the 74.5°N transect we only had 12 niskin bottles so instead of closing two at the same depth we drew two samples from one niskin. The depth was varied from station to station. These duplicates therefore also give information on whether our sampling method (different samplers etc) affects the carbon values.
 - There is no duplicate on stations 335 and 341
 - Using all duplicates we have a mean precision of $1.3 \pm 1.0 \mu\text{mol kg}^{-1}$ for DIC.
- Comparison with historical cruises:

- The DIC data from this cruise was run through the 2QC toolbox (Lauvset and Tanhua, in prep). The results suggest that there is a $4.5 \mu\text{mol kg}^{-1}$ bias in the data (Figure 9). Please note that these are preliminary results and that the 2QC needs to be redone after a thorough primary QC has been performed on the data.

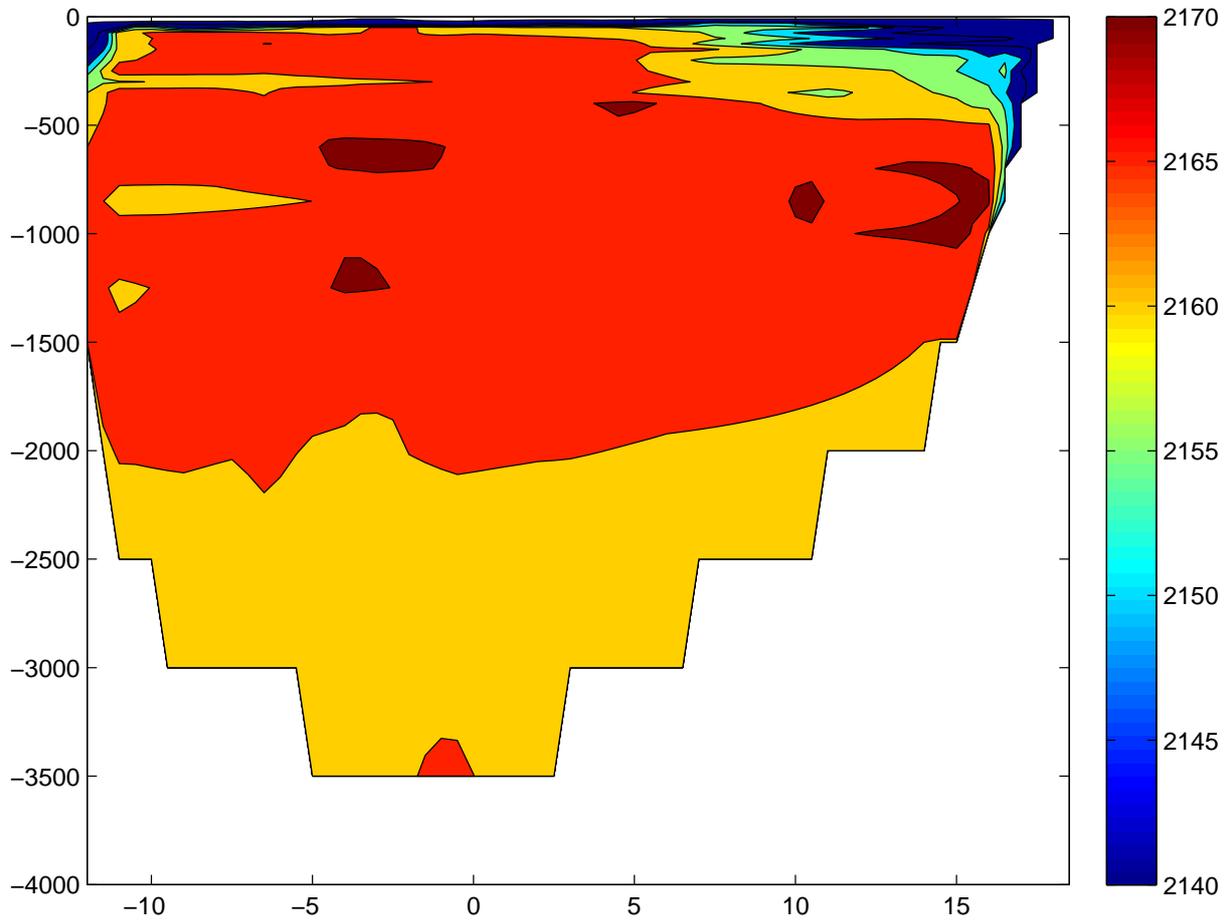


Figure 8. DIC measured on 58GS20130717. The data have been corrected to CRMs and were gridded in the following layers [0 10 30 50 75 100 125 150 200 250 300 350 400 500 600 700 850 1000 1250 1500 2000 2500 3000 3500 4000] for every 0.5° longitude.

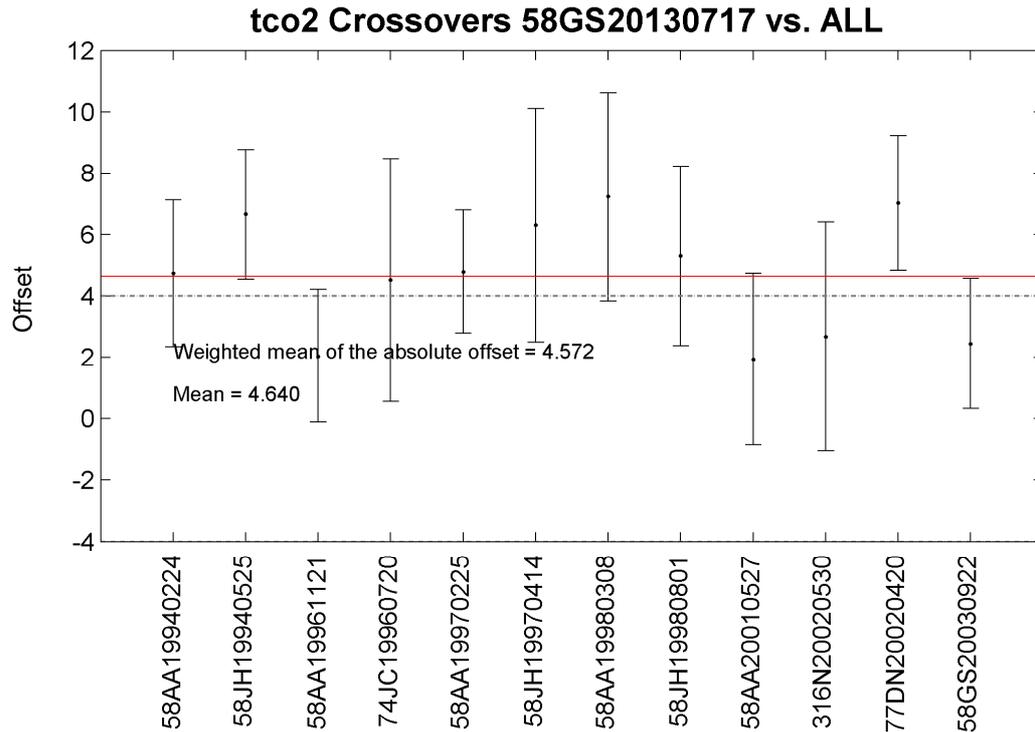


Figure 9. Summary of offsets for the 2013 cruise when compared to historical cruises (see x-axis). The limits set for DIC is $\pm 4 \mu\text{mol kg}^{-1}$.

Alkalinity

- We analyzed for alkalinity by titrating the samples with HCl, using a VINDTA AT instrument from Marianda, and used a Gram fit to get the alkalinity (Figure 10). The system generally worked very well for the entire cruise, but there are some software issues.
- CRMs were run before and after each position using the same sequencing as for DIC. The accuracy on the CRM values was approximately $+20 \mu\text{mol kg}^{-1}$.
- Duplicates:
 - Duplicates were taken as described for DIC
 - There is no duplicate on station 335, 337, and 341.
 - Using all duplicates there is a mean precision of $1.0 \pm 0.79 \mu\text{mol kg}^{-1}$ for alkalinity
- Comparison with historical cruises
 - The alkalinity data from this cruise was run through the 2QC toolbox (Lauvset and Tanhua, in prep). The results indicate that there is a bias of $2.5 \mu\text{mol kg}^{-1}$ in the alkalinity data (Figure 11).

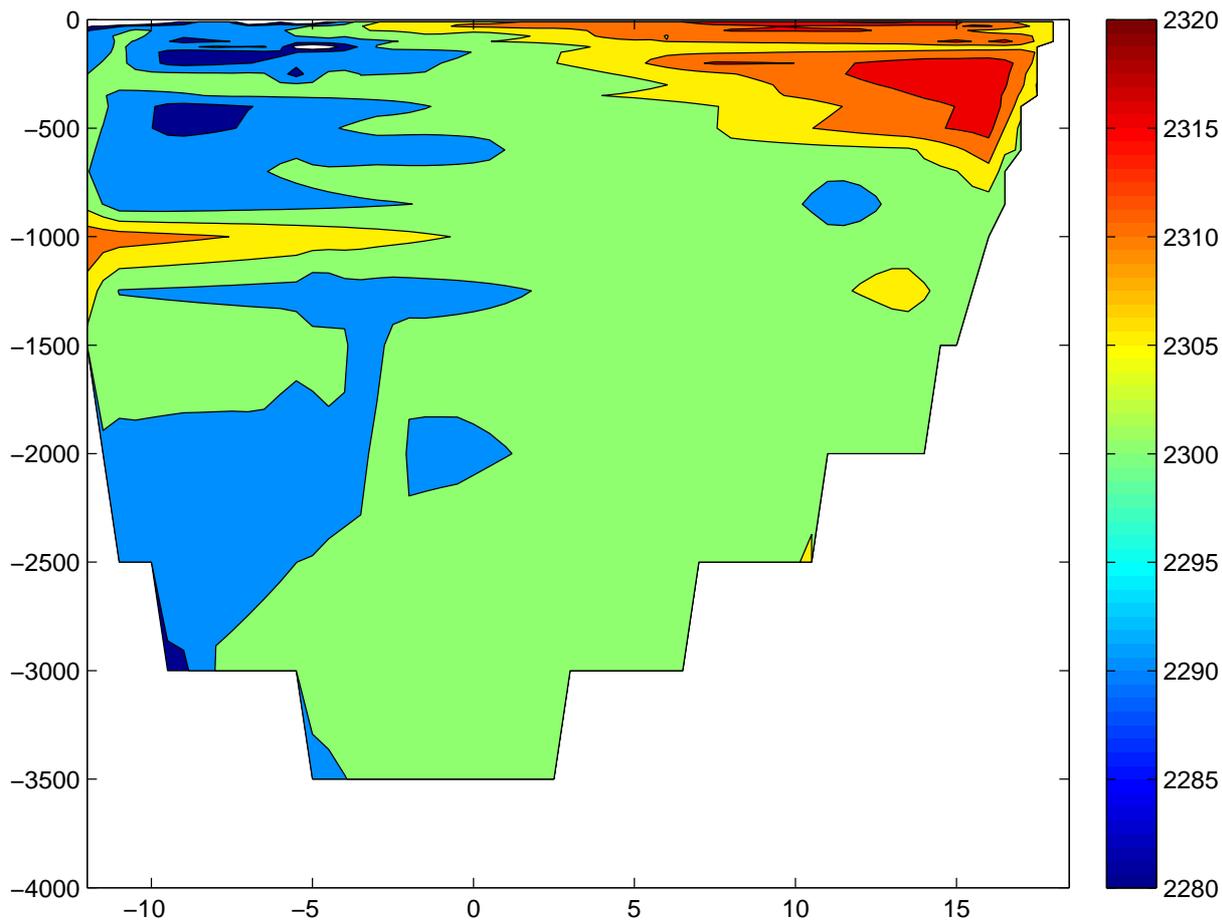


Figure 10. Alkalinity measured on 58GS20130717. The data have been corrected to CRMs and were gridded in the following layers [0 10 30 50 75 100 125 150 200 250 300 350 400 500 600 700 850 1000 1250 1500 2000 2500 3000 3500 4000] for every 0.5° longitude.

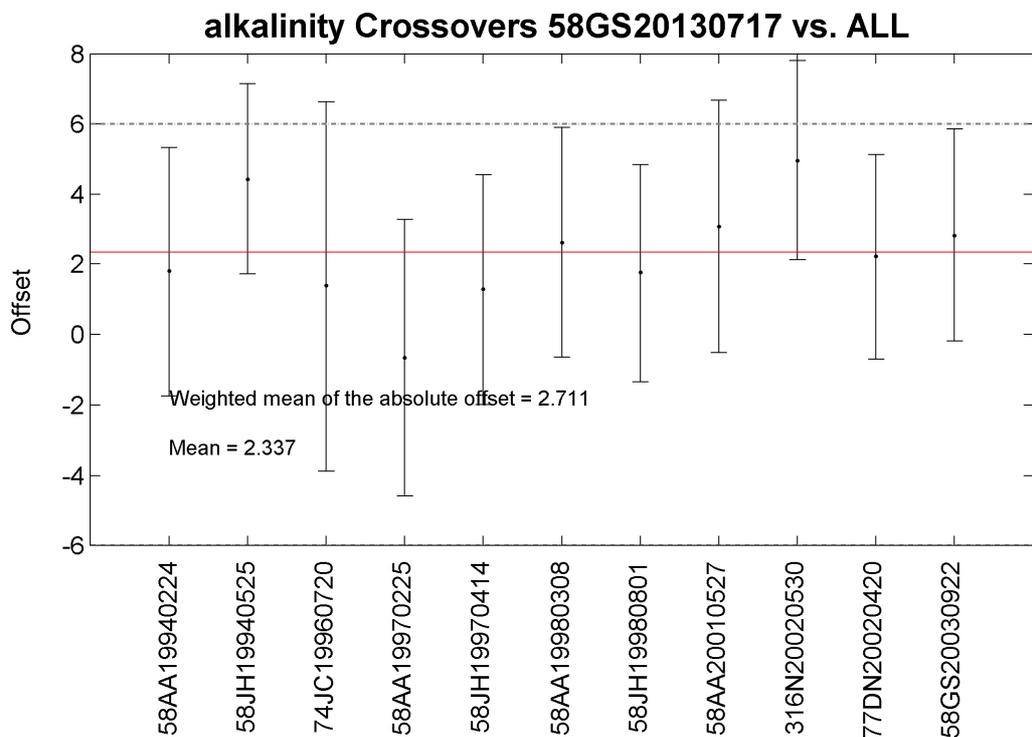


Figure 11. Summary offset figure for alkalinity on this cruise when compared to historical cruises (see x-axis). The limit set for alkalinity is $\pm 6 \mu\text{mol kg}^{-1}$.

Dissolved oxygen

Responsible: Mirjam Glessmer

A Winkler system (Figure 12) was brought onboard G.O. Sars to measure dissolved oxygen concentrations along the 75°N and 74.5°N sections at the same depths as other chemical tracers would be measured. However, most likely due to contaminated reagents, no sample could be measured. The reason(s) for all the problems with dissolved oxygen on this cruise are still not completely known or understood. For a detailed account of the problems that occurred and the steps that were made to solve them see the separate report by Mirjam Glessmer.

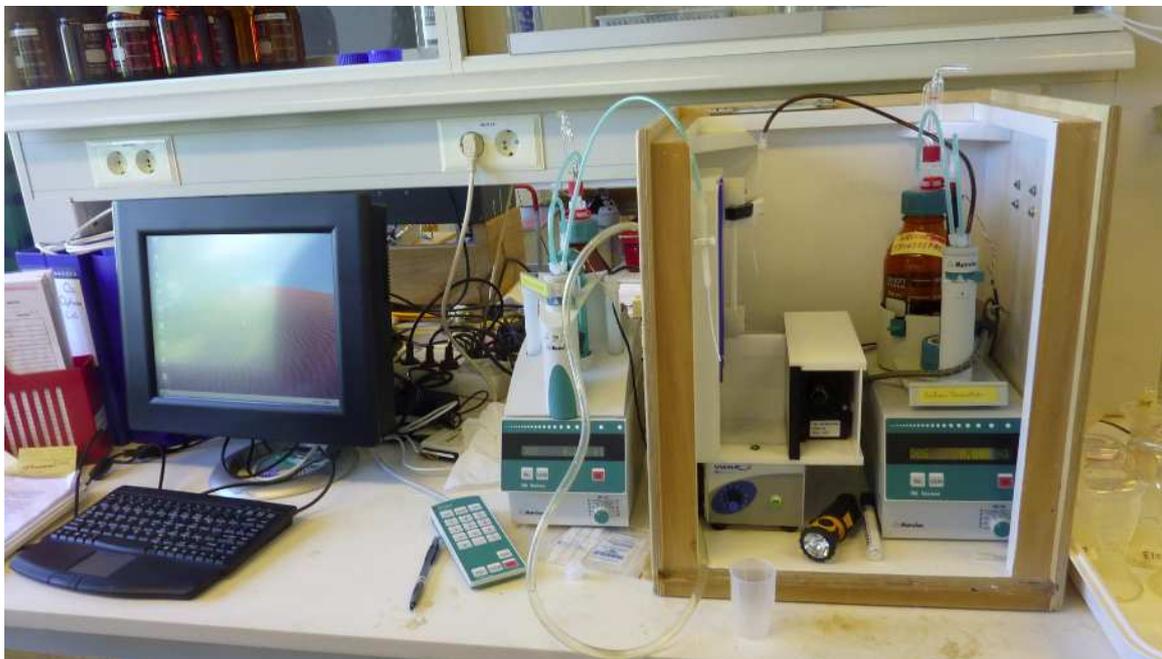


Figure 12: Setup of the Winkler system (Photo: Tor de Lange)

And specifically for this Winkler system, there are a couple of things that need to be tested before bringing it on a cruise again:

- The piston of the KIO_3 dosimat “wobbles” at the very end of the filling cycle, when it is at its lowest position. Check whether that has any influence on the dispensed volume.
- Some of the glass bottles are stained yellow, for example no 32, 33, 35 and 52. This should not have an influence on their functionality, but it might be worth checking that the UV gain is not too low due to the discoloration.

- The KIO_3 temperature sensor is not working. There is a manual override so measuring is still possible, but it should be fixed.
- The Winkler system needs extra equipment to make it easier to work with: a flash light to check for bubbles in the dosimat tubing, more stirring magnets (and of similar size to make sure different shapes don't add uncertainty), a 1.5mm screw driver to adjust the UV detector's gain.

Trace gasses (CFCs, SF6)

Responsible: Emil Jeansson

These tracers are measured by a purge-and-trap instrument (built at the Bjerknes Centre Chemical Oceanography lab in 2008/2009) combined with a gas chromatograph with electron capture detector. Unfortunately there were lots of problems with the instrument during the cruise, and only half a station could successfully be measured. These few data are discarded. There are many reasons for the failed measurements, where some are known and some unknown. Without going into all these in detail the bottom line is that the necessary pre-cruise testing could not be performed as planned due to several reasons. This was a combination of problems with the computer(s), the communications between the computer(s) and the instrument, lack of manpower (Emil Jeansson partly on paternity leave in combination with insufficient technical support), and the fact that the instrument had not been started up since the last G.O.Sars cruise, which was as long time ago as 2009. Many of the problems could probably have been avoided with a more successful pre-cruise testing of the instrument.

Technical issues

We are having some issues with the CTD:

- 1) The synthetic fiber cable is not compatible with the CTD sensor on the big 24 bottle rosette (physically not possible to connect the two)
- 2) The synthetic fiber cable also only has one optics line so when using it we cannot run both the CTD and the LADCP at the same time
- 3) The steel cable can only go down to 2000 m due to its weight. We have been given permission (from the captain and head instrument technician) to go 3300 m. This is pushing the limits though so we have chosen not to do this. Instead we will do double casts on the deepest stations (>2500 m) and use 12 bottles on the rest.

The new plan is to close the seven (7) deepest niskin bottles on the first cast and the remaining ten (10) on the second cast. There will be a duplicate on each cast. This will allow us to sample the deepest water in the Greenland Sea. We are also less dependent on excellent weather conditions for sampling.

Sampling routine:

- 1) Trace gases
- 2) Oxygen
- 3) DIC and alkalinity (one 250mL bottle)
- 4) C-14 (500mL bottle)
- 5) C-13
- 6) Nutrients
- 7) Salinity (not taken on all depths)

We had reason to believe that the distilled water was contaminated and decided to change the deionizing column on the pure water system. Without a manual on board we did not dare do anything else to the system as we are too dependent on pure water. Changing the deionizing column introduced a lot of air into the system and it took ~24 hours to get the system running properly again. For future cruises we should bring a pure water system with us for backup. Generally the pure water system on board needs more regular maintenance – especially regarding cleaning the holding tank and maintaining and changing the UV-light regularly.

These issues were brought up in the technical report sent to the IMR. Below is the communication from the IMR shipping department on September 3, 2013 (Norwegian only):

“Det er Rederi sitt ansvar siden det er "veggfast" materiell. Hans Terje Meland vil koordinere vedlikeholdet fra Rederi, og første post på programmet er å finne frem til produsent, servicefirma og teknisk dokumentasjon for å få gjennomført vedlikehold/repasjon. Neste post er å få inn vedlikeholdsrutiner i TM-Master.»

As of September 3, 2013 a complete manual for the pure water system has been located and placed onboard the ship.

Towards the end of the cruise the pure water system seemed to be broken. The holding tank was accidentally emptied below the intake for the deionizing column. We refilled the tank and placed it higher than the pump on the deionizing column which should restore flow within a few hours. We also used a smaller bottle to fill the tube between the tank and the column to kick-start the pump. After ~24 hours there was still no flow and it appeared like the pump is not working, i.e. we cannot see air or bubbles coming into the column either like we could after it was changed. The cruise leader on the MAREANO cruise starting the day after this one ends (Lis lindal Jørgensen) was informed about the issue and advised to bring her own pure water system should that be required for the cruise.

Autonomous underway measurements:

Underway pH (Responsible: Siv K. Lauvset)

Underway pH measurements were made for five days towards the end of the cruise.

However, there were no usable data.

Underway fCO₂ (Responsible: Siv K. Lauvset)

Due to a broken equilibrator pump, which was not discovered during the cruise, there are no usable fCO₂ data from the cruise. Note that we also had no spare pump with us so discovering the broken part during the cruise would not have helped.

Underway O₂/Ar (Responsible: Emil Jeansson)

Underway measurements of the ion current ratio between oxygen and argon (O₂/Ar) are performed by means of equilibrator inlet mass spectrometry using the EIMS system (Cassar et al., 2009). Both physical and biological processes influence the concentration of oxygen in the surface ocean. As O₂ and Ar have very similar physical properties (e.g. solubility and temperature dependence), measuring the ratio allows the removal of the physically driven part of the oxygen flux, and thus determination of the biologically driven contribution.

$$\Delta O_2/Ar = ([O_2]_{meas}/[Ar]_{meas})/([O_2]_{sat}/[Ar]_{sat})-1$$

Equation 1

This “biological O₂ supersaturation” reflects the net metabolic balance between photosynthesis and respiration (Cassar et al., 2009), hence the net community production (NCP):

$$NCP=k*(\Delta O_2/Ar) * [O_2]_{sat} * \rho$$

Equation 2

where k is the gas exchange coefficient for O₂ (m d⁻¹), $[O_2]_{sat}$ is the equilibrium concentration of O₂ in the mixed layer (μmol kg⁻¹) and ρ is the mixed layer density [kg m⁻³]. The employment the EIMS system represents, to the best of our knowledge, the very first study of its kind in this region.

The resulting O₂/Ar signal, and hence the biological oversaturation, is seen in Figure 13 below. All positive values indicate biological production, and negative values indicate a flux of oxygen from the atmosphere and into the sea surface.

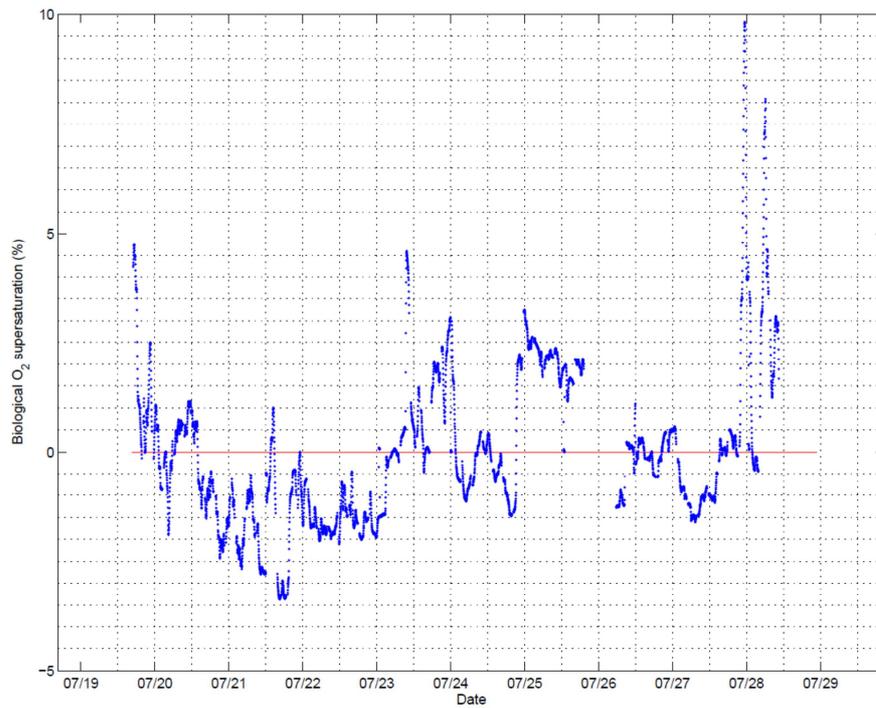


Figure 13. Biological super saturation (%), along the 75°N section in July 2013, calculated from O₂/Ar underway data.

The other parameters needed to calculate NCP are taken from the ship data, which will be retrieved as soon as possible; they should have been collected before we left the ship.

Samples taken onboard to be analyzed on land:

C-14 (PI: Alan R. Gagnon; Responsible onboard: Dominic Clement, Jerry Tjiputra)

500mL samples were taken. The bottles were poisoned with 100 μL HgCl_2 and sealed. The sampling procedure (including poisoning and sealing) was carried out according to WHP procedures and methods from June 2003 (attached). All samples were shipped to Alan R. Gagnon at Woods Hole Oceanographic Institute (WHOI) at the end of the cruise. The analysis will be performed at WHOI.

C-13 (PI: Are Olsen; Responsible onboard: Dominic Clement, Marie Eide, Benjamin Pfeil, Jerry Tjiputra)

50mL samples were taken. The bottles were poisoned with one drop HgCl_2 and sealed. All samples were shipped to the University of Bergen (UiB) in Bergen at the end of the cruise. The samples were analysed in Ulysses Ninneman's laboratory at UiB. Using all duplicates the precision is better than 0.07‰. For the triplicates that were run the precision was better than 0.05‰ (1σ). This is better than the variation in the house standards run in the lab (0.085‰, $n=96$). Figure 14 shows the spatial distribution of dC-13 along the cruise transect.

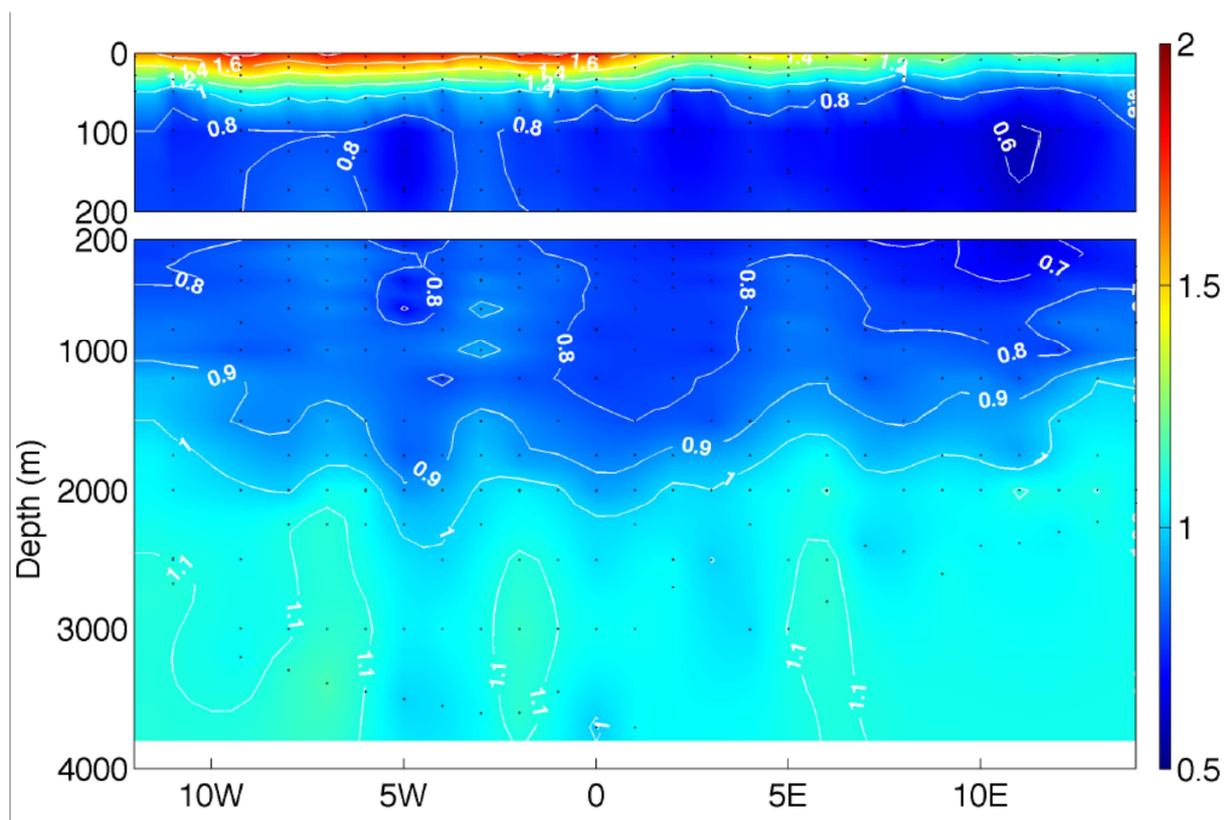


Figure 14. Map of dC-13 measured from samples taken on the GOSars cruise.

Nutrients (PI: Linda Fonnes; Responsible onboard: Marie Eide, Benjamin Pfeil)

20mL samples were taken. These were poisoned with 200 μ L chloroform according to standard procedures and refrigerated. All samples were shipped to the Institute of Marine Research (IMR) in Bergen at the end of the cruise. The samples were analysed for nitrate, phosphate, and silicate post-cruise by Linda Fonnes at the IMR nutrient laboratory in Bergen. The data have been submitted to the Norwegian Marine Data Center. Using the duplicates (see section about DIC for details on duplicate sampling) the mean precision on nitrate is 0.092 ± 0.11 , on phosphate is 0.012 ± 0.015 , and on silicate is 0.079 ± 0.20 . This means an approximately 1% precision on all nutrient parameters – somewhat less for nitrate and somewhat more for phosphate. Figure 15, Figure 16, and Figure 17 show the results of the crossover analysis run for nutrients. Phosphate seems to be 10% too high, and while silicate shows the expected temporal trend.

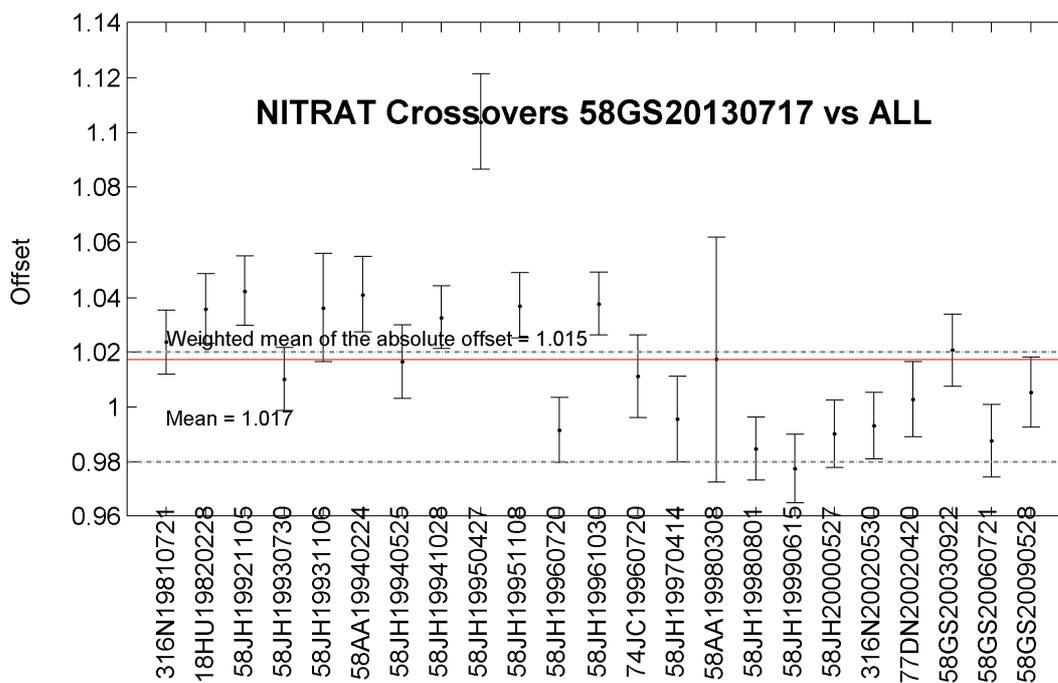


Figure 15. Crossover results for nitrate measured at IMR after the cruise.

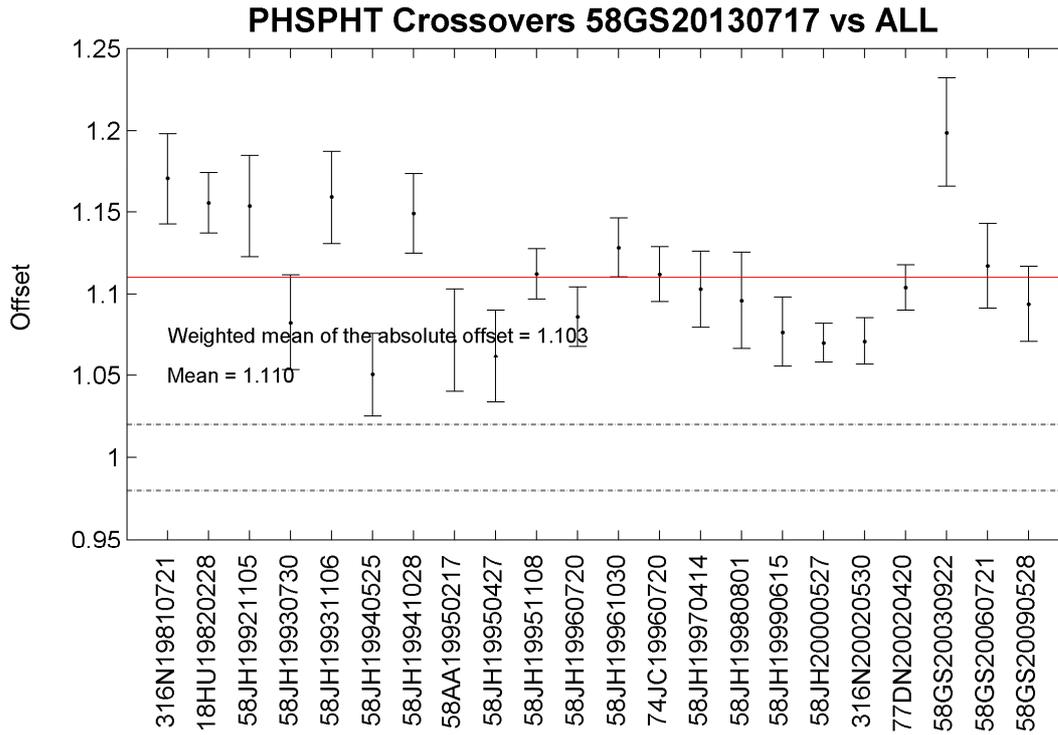


Figure 16. Crossover results for phosphate measured at IMR after the cruise.

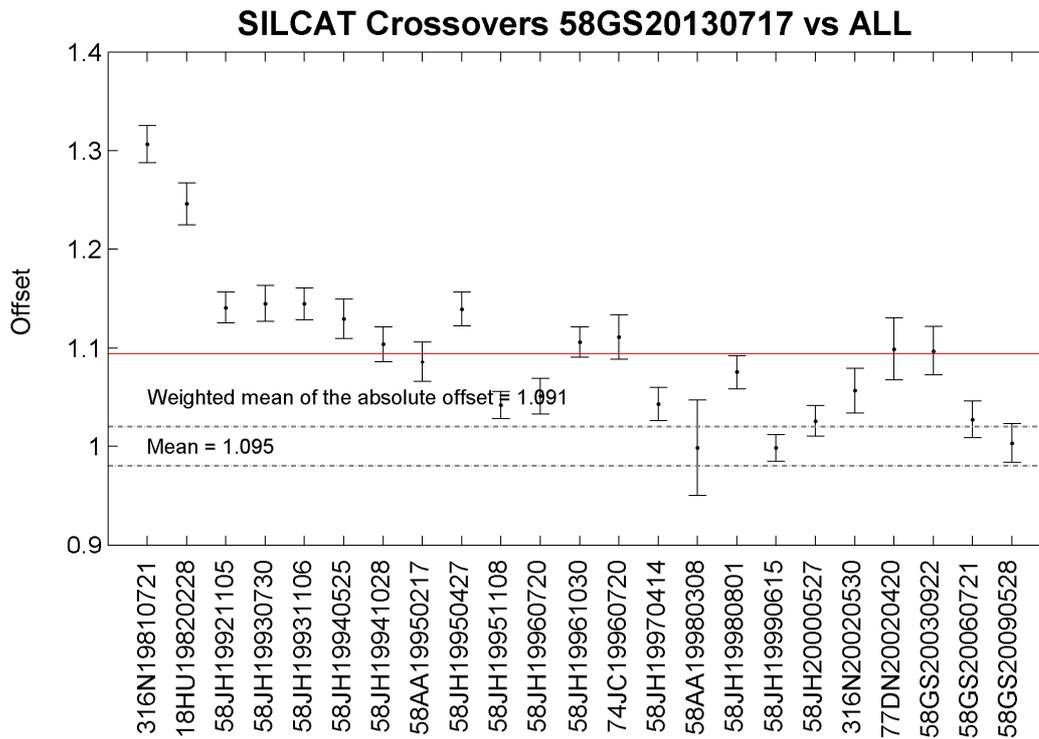


Figure 17. Crossover results for silicate measured at IMR after the cruise.

Salinity (PI: Helge Sagen; Responsible onboard: Martin Dahl)

This cruise did not follow WOCE standards for salinity. Two bottles per position were taken and used to calibrate the salinity sensor on the CTD. Note: On the deepest part of the transect

we did two stations per position – one cast to get water samples from deeper than 500-1000 m and the second cast to get water samples from shallower than 500-1000m. The CTD-technicians sampled for salinity and shipped all samples back to IMR in Bergen where they were analysed. Based on the bottle salinities, the calibration factor for the CTD salinities was -0.002 and these were adjusted accordingly. See section on CTD measurements for details.

References

Cassar, N. et al., 2009. Continuous High-Frequency Dissolved O₂/Ar Measurements by Equilibrator Inlet Mass Spectrometry. *Analytical Chemistry*, 81(5): 1855-1864.