2008-30 NO_3 Deep Nutrient Comparison and Data Report

Kristina Brown and Fiona McLaughlin

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Background:

Seawater samples collected and analyzed for the determination of Nitrate (NO_3) during the Canada Basin JOIS Cruise 2008-30 aboard the CCGS Louis S St. Laurent appeared to fall on the low side of historical deep water data distributions (> 250m depth as depicted in Appendix Figure A1). When individual stations were compared along the cruise track, this deviation from the trend in historical deep water values was inconsistent between different station profiles and was slightly more pronounced in the eastern portion of the basin (as depicted in Appendix Figures A2 CB3-CB11 Western-Canada Basin & A3 CB16N-CB29 Eastern-Canada Basin). Instrument operation and standard runs for all three nutrient parameters (NO_3, SiO_4, H_3PO_4) were observed to behave well throughout the duration of the cruise, with WAKO, Kanso AS, & Med Check standard measurements for NO_3 varying within acceptable limits between analysis runs (Appendix Figure A4 a, b). However both the Kanso AT standard and the deep seawater reference sample (CABOS 600m) run as a daily check standard both exhibited a linear decrease in concentration of ≈ 0.4 and 1.2 mmol/m^3 respectively (Appendix Figure Ac and 4d, slope for 4d = -0.0341, R^2 = 0.87), suggesting that drift in instrument analysis could explain why samples in the eastern basin (sampled in the second half of the cruise, Figure A3) have a more pronounced offset from historical trends than those in the western basin (sampled in the first half of the cruise, Figure A2).

As detailed in Linda White's nutrient analysis report, the main colorimeters used for nutrient analysis onboard the LSSL in 2008 were significantly damaged during container loading at IOS in July 2008. Damage to the main colorimeters was found to be extensive and although parts were replaced, the colorimeter is believed to be the main contributor to variability in the data (see Linda White's 2009 nutrient analysis report). Despite this known problem, NO_3 standards themselves did not indicate any change in instrument operation throughout the duration of the cruise (Appendix Figure A4 a, b), and in order to determine if progressive instrument drift contributed to observed low NO_3 values (> 250m) in the 2008-30 data set, deep water data from central basin stations visited during the 2008-30 cruise were compared with average deep water values from historical LSSL cruises 2003-21, 2004-16, 2005-04, & 2006-20. The methods of comparison and corrections applied to the 2008-30 NO_3 values are presented below.

Investigation Methods:

To determine if instrument drift was a factor in low reported data values, NO_3 data collected and analyzed aboard the LSSL during the 2008-30 cruise were evaluated against historical data from deep water stations throughout the Canada Basin. Before use in this comparison, deep water NO_3 samples from CB stations visited from 2003-2006 (LSSL 2003-21, 2004-16, 2005-04, & 2006-20) were evaluated using 3 criteria:

(1) maximum station depth >1500m (all end up being deeper than 3000m);
(2) at least three years of data between 2003-2006 for a particular station & the sampling depth compared; and
(3) average values at particular depth designations (2500, 3000 etc) needed to have been sampled within 50m of that depth (this criterion needed to be loosened a little - but almost all depth designations were sampled within 50m of the depth with only 4 comparisons made within 200m from depth)

Data from the 2003-2006 data set found to fulfill these criteria were then used to determine average deepwater values for the basin, as well as for each station/depth compared. 2008-30 data values were then evaluated against deep water concentration averages at each specific depth to determine the extent to which these values deviated. Calculated depth-average values used for comparisons (AVG 2003-2006) always exhibited a standard deviation within ±0.3 mmol/m^3, with most (90%) falling within ±0.2 mmol/m^3. In total, 42 deep water samples analyzed over the 2008-30 cruise were compared with average values (2003-2006) fulfilling the aforementioned criteria.

Results: Summarizing Historical Data (2003-2006)

Historical Data Averages

Table 1 indicates the stations used in the following comparison, where each station included fulfilled the criteria above. Table 2 lists average NO_3 values & standard deviations for all historical data (2003-2006) used in comparisons, as further depicted in Appendix Figure A5 & Appendix Figure A6, which illustrates the consistency within which averages from individual stations compares to basin wide averages.

Table 1. 2003-2006 Stations utilized in 2008 vs (2003-2006) deep water comparison

CB2	CB3	CB4	CB5	CB6	CB7
CB8	CB9	CB10	CB11	CB13	CB15
CB17	CB18	CB21	CB22	CB27	CB29

Table 2. 2003-2006 Deep Water NO_3 Averages

2003-2006 Data	NO_3 [mmol/m^3]	StDev
AVG ALL DEEPER THAN 1500m	14.4	0.5
AVG ALL BTW 1500 - 2000m	13.6	0.3
AVG ALL DEEPER THAN 2000m	14.7	0.2

Use of Station Deep Water Averages vs Station/Depth Averages

Comparing averages generated for the depth intervals listed in Table 2, 1500-4000m, 1500-2000m, 2000-4000m, it can be observed that the 1500m-4000m average is not a good representation of NO_3 concentrations below 1500m, as there is a clear curve to the profile from 1500 - 2000m (Appendix Figure A6). Instead, using an average from 2000 - 4000m (14.7 +/- 0.2) and an average from 1500-2000m (13.6 +/- 0.3) appears to better represent these separate deep water values (Note that 2000m samples were not included in the 1500-2000m average, just up to 2000m, whereas 2000m samples were included in the 2000m-4000m average determination).

Average (2003-2006) values for each deep water depth (ie. 1500m, 2000m, 2250m, 2500m, 3000m etc) at each station, were also used to evaluate 2008-30 NO_3 data. Appendix Figure A6 illustrates that these values better represent differences accross the basin, and yield more appropriate comparisons when considering deviations in the 2008-30 data set. It should be noted from Appendix Figures A5 & A6, however, that although there are observed differences between average values accross stations and depths, standard deviations of these values are quite close to the analytical error at 2 Sp (NO_3 = 0.2 mmol/m^3) and therefore might be well within expected error. However, as data in Appendix Figure A6 shows, the variability is much greater than +/- 0.2 at some stations, most notably at CB21, CB27 and CB7.

Inclusion of 2004 & 2007 Data

One consideration about this approach is that 2007 data were not included in making comparisons. Removing 2008-30 data from Appendix Figure A1 illustrates that deep water NO_3 data analyzed onboard in 2007 indeed fall to the low side of the historical data distribution, however much less so than values reported in 2008.

In addition, some deep water values in 2004 (CB22-CB29) appeared to be quite high (>15.2 mmol/m^3) and will have contributed to increasing the average value overall for 2000 – 4000m (Appendix Figure A3, Panel 2 & Table 2). When individual station/depths were compared it was decided that these high values would be removed from the 2004 data set for stations CB21, CB22, CB27, & CB29 before comparisons with 2008-30 data were made. Despite these few high values it is felt that the averages used in this comparison are robust and are not weighted heavily by the few remaining value > 15.0 mmol/m^3 remaining in the comparison data set (2003-2006).

Results: 2008-30 NO_3 Drift

Figure 1 illustrates the results of the comparison of 2008-30 NO_3 values with average deep water values for each respective station. In this figure, pink dots illustrate data covering the depth interval of 2000-4000m, and blue dots covering 1500-2000m. As indicated in the graph, separate average values were used for each depth interval (as in Table 2). The Y axis depicts the deviation of 2008 values from the 2003-2006 depth average, with plotted values calculated by subtracting the average 2003-2006 value for the two depth intervals (ie. 2000-4000m =14.7 or 1500-2000m = 13.6) from the measured 2008 value, [(2008 – AVG(2003-2006))]. The x-axis plots sample number, which increases with time over 2008-30 cruise (ie. values are plotted in order of sampling, not necessarily analysis order). No frozen samples were included in this analysis or in plots depicted within this report. Figure 1 illustrates a clear decreasing trend in the deviation of NO_3 values from average (2003-2006) deep water NO_3 over the course of the 2008 cruise.

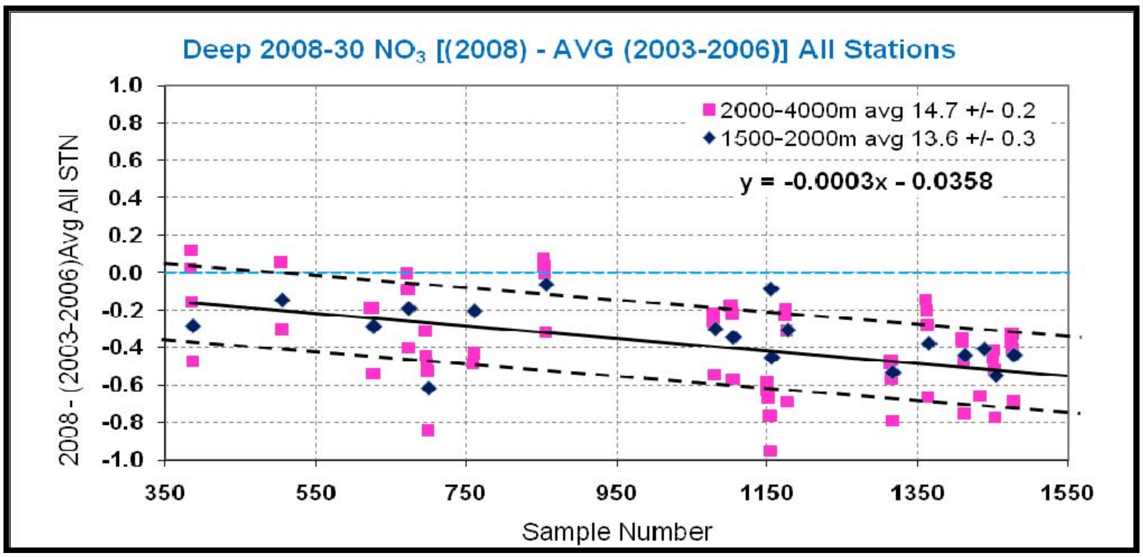


Figure 1. Average Difference [2008 – (2003-2006 Average)] vs Sample Number. NO_3 data compared only at stations > 3000m, as listed in Table 1, frozen samples not included. 2003-2006 Average values as in Appendix Figures A5 & A6. Pink dots cover the depth interval of 2000-4000m and blue dots 1500-2000m. Separate average values were used for each depth interval as indicated on graph. Y-axis shows deviation from the average 2003-2006 value over the depth range; solid black line represents the trendline described by y = -0.0003x – 0.0358; black hatched lines are the expected error limits projected from the trendline, +/- 0.2 $mmol/m^3$, or the reported Sp for the 2008 data set.

Similarly, Figure 2 illustrates a negative slope in the plot of NO_3 deviation with respect to sample number. In this figure, 2008 NO_3 values are compared with the average (2003-2006) value for the depth sampled (within 50m) at each specific station. As in Figure 1, no frozen samples were included. Figure 2 further illustrates a trend in progressively decreasing NO_3 values over the course of the cruise with values dropping lower than the average value from 2003-2006 for each station & depth sampled.

Although Figures 1 & 2 illustrate the differences between measured NO_3 values and average deep water concentrations measured from 2003-2006, they are plotted against sample number along the x-axes, and not necessarily their order of analysis. Date of analysis is plotted below in Figure 3, further reinforcing the clear negative slopes seen in Figures 1 & 2. Figure 3 also illustrates the large inter and intra day variability of these data.

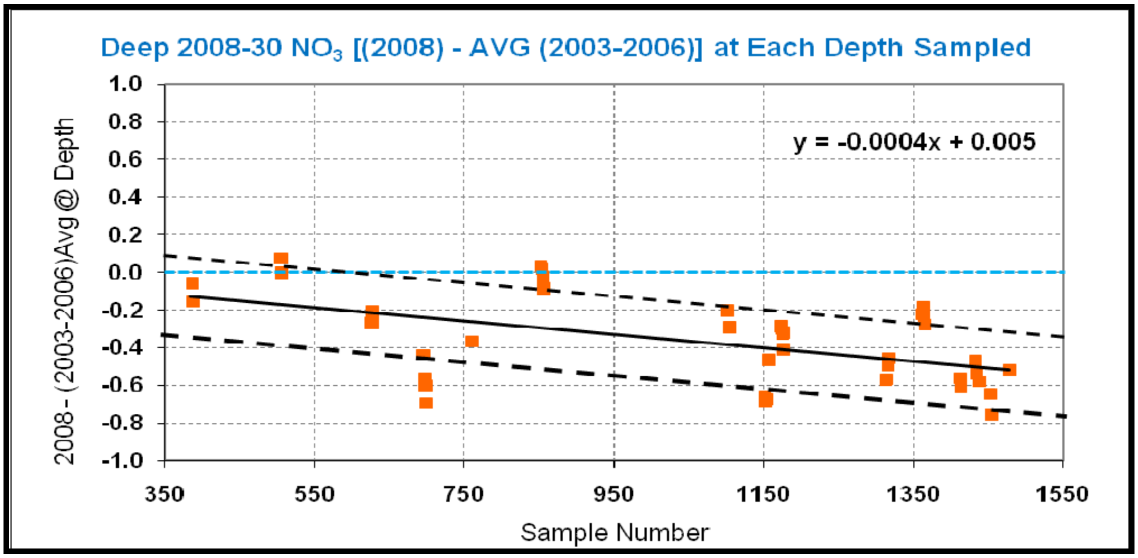


Figure 2. Average Difference [2008 – (2003-2006 Average @ Station & Depth)] vs Sample Number (not necessarily run order). ALL NO_3 data compared only at stations > 3000m, as listed in Table 1, frozen samples not included. 2003-2006 Average values as in Appendix Figures A5 & A6, with comparisons based on individual station averages at various depths (+/- 50m) ; black hatched lines are the expected error limits projected from the trendline, +/- 0.2 mmol/m^3, or the reported Sp for the 2008 data set.

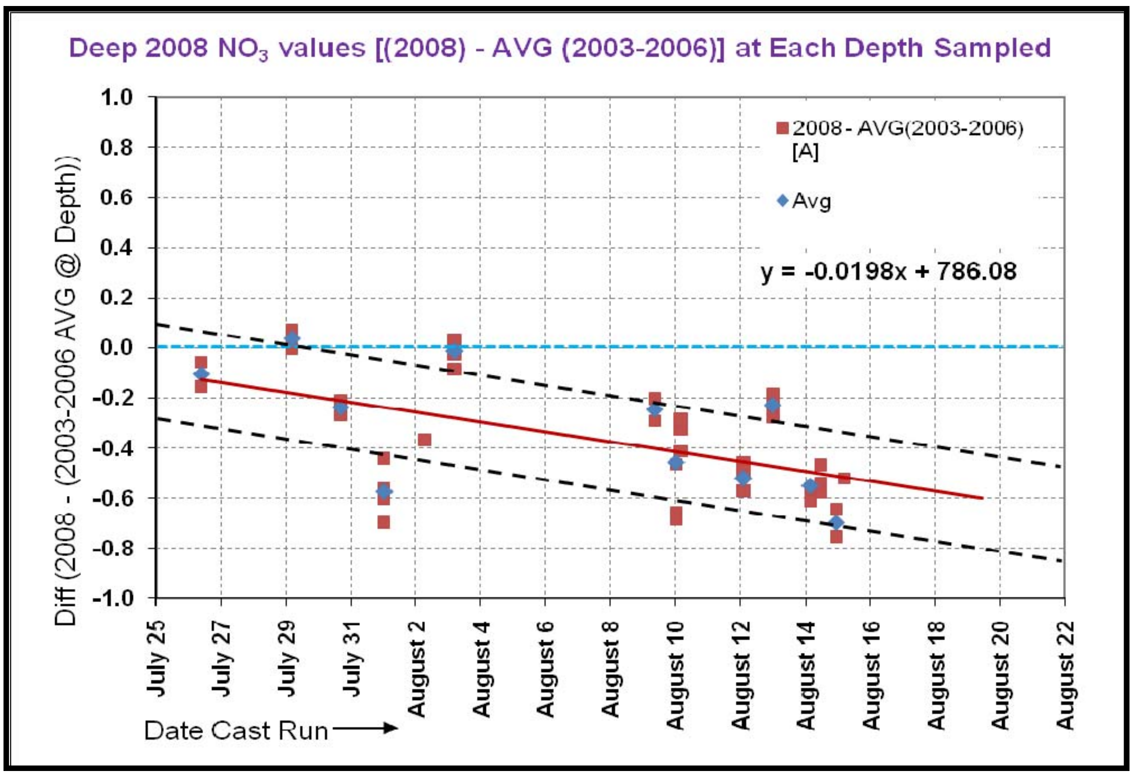


Figure 3. Average Difference [2008 – (2003-2006 Average @ Station & Depth)] vs Date Run. Data NO_3 data compared only at stations > 3000m. 2003-2006 Average values as in Figures 4 & 5, with comparisons based on individual station averages at various depths (+/- 50m). Blue squares illustrate average difference for each run day; solid red line represents the treadline fit to the data, defined by y = -0.0198x + 786.08; black hatched lines are the expected error limits projected from the trendline, +/- 0.2 mmol/m^3, or the reported Sp for the 2008 data set.

Results: Data Correction

The slope depicted in Figure 3 (y = -0.0198x - 0.0174, where x is day of analysis starting Zero at July 21st where the first deep station was analyzed; Figure 3 illsutrates the same slope but with an intercept that reflects true analysis date) was used to apply a linear correction to NO_3 data collected and analyzed aboard the LSSL during the 2008-30 cruise. This is based on the assumption that the negative slopes depicted in the previous figures are a result of a linear drift in the instrument output over the course of the cruise, and not due to daily fluctuations in the instrument response. As noted above, however, Figure 3 also illustrates substantial variation in measurements carried out within the same day, overprinted with an apparent trend in negative drift over the duration of the cruise. The error at the 95% confidence limit based on duplicate analysis during the cruise is +/- 0.4 $mmol/m^3$ (2 sigma), limits which envelope and account for the visible within-day drift seen in Figure 3 (see Within-Day Drift & Reported Standard Error section below). With this consideration in mind, 2008-30 NO_3 data are only corrected for the instrument drift calculated from the deep water comparison depicted above.

Figure 4 illustrates the data depicted in Figure 3, including recalculated data values corrected for instrmuent drift according to the equation y = -0.0198x - 0.0174, where x is day run in order from beginning of cruise (July 21st = 0). Red squares depict original data, as in Figure 3, whereas green triangles illustrate the corrected data. The flat (slope = -0.00003) trendline associated with corrected 2008 data illustrates that remaining variability in the values is not dependant on the date samples were analyzed, and therefore, is no longer associated with instrument drift.
The 2008-30 NO_3 data set was therefore corrected using the linear drift correction depicted by the trendline equation, y = -0.0198x - 0.0174, where x is day run in order from beginning of cruise. The sole exception is station CB18 for which no correction was applied. When corrected the data were too high and would require an SD of +/- 0.5 $mmol/m^3$. CB18 was analyzed onboard August 13, 2008. As illustrated in Appendix Figures A2 & A3, data points collected from deep water stations along the western (CB3-CB11) and eastern (CB16N to CB29) sides of the Canada Basin are now compared to corrected data values, as seen in Appendix Figures A7 (deep water – CB3-CB11) & A8 (250m to 4000m – CB3-CB11), and Appendix Figures A9 (deep water – CB16N – CB29) & A10 (250m to 4000m – CB16N-CB29). Examples of individual station profiles are depicted in Appendix Figures A11 – A14, where blue filled circles denote original 2008-30 NO_3 data, and red triangles denote corrected data points. The full 2008-30 NO_3 data set and corrected values are listed in the Appendix Table A24.

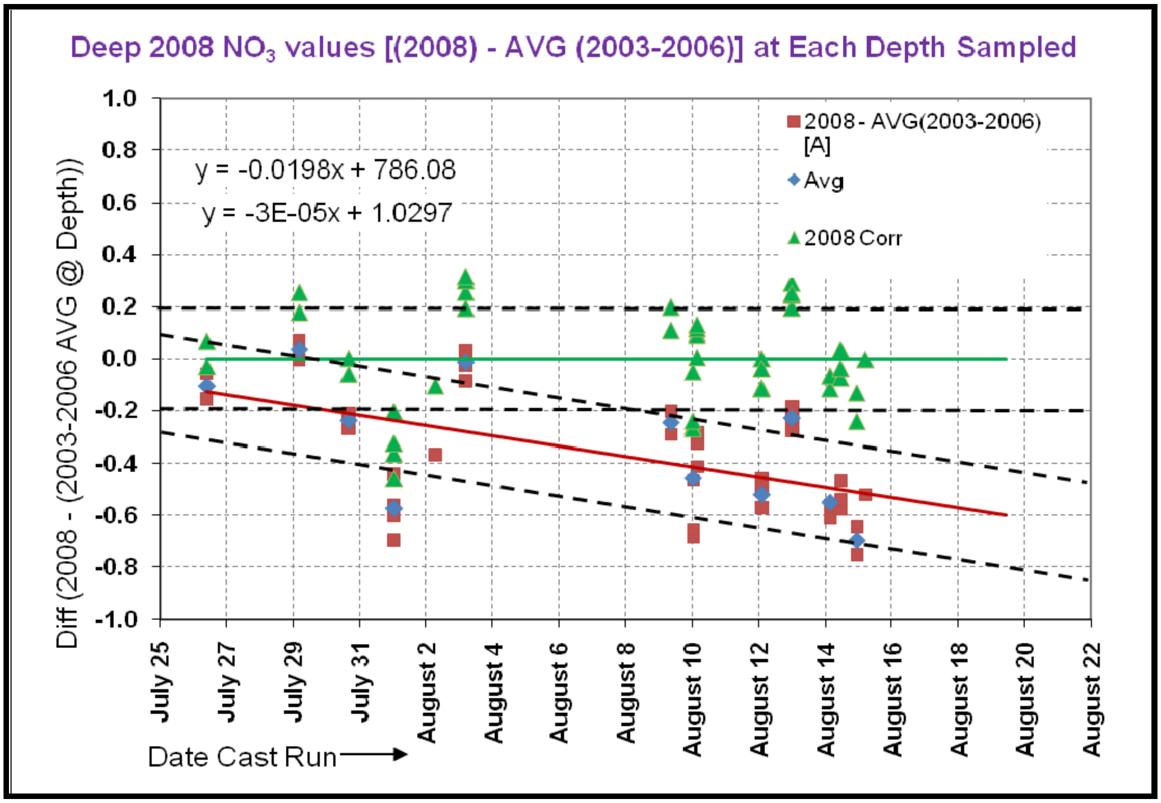


Figure 4. Original 2008 Data: [Red Squares] Average Difference [2008 – (2003-2006 Average @ Station & Depth)] vs Date Run. Data NO_3 data compared only at stations > 3000m. 2003-2006 Average values as in Figures 3, with comparisons based on individual station averages at various depths (+/- 50m). Blue squares indicate average difference for each run day. Corrected 2008 Data: [Green Triangles] Average Difference [2008Corrected – (2003-2006 Average @ Station & Depth)] vs Date Run, values corrected according to the treadline depicted for original data (y = -0.0198x - 0.0174, where x is day run in order from beginning of cruise, July 21^{st} = 0). Black hatched lines are the expected error limits projected from each trendline, +/- 0.2 $mmol/m^3$, or the reported Sp for the 2008 data set.

<u>**Corrected Data Specifics:**</u>

<u>**Any value less than 0.8 $mmol/m^3$ was not corrected**</u>

Station CB 18 was not corrected – large inter day variablity and when corrected values were too high whne compared to other years.

Within-Day Drift & Reported Standard Error for 2008-30 NO3 Data Set

The reported standard error (standard deviation, not Sp) as calculated from duplicate analyses (n= 247) is **+/- 0.2 $mmol/m^3$** (see Linda White's 2008-30 cruise report). Which gives a standard error at the 95% confidence limit as +/- 0.4 $mmol/m^3$ (2 sigma); this 95% confidence interval accounts for the within-day drift of the analysis system, as evidenced by differences in Canada Basin deep water (> 2500 m) sample values depicted in Figure 3.

Comparison to Frozen Samples

TER (TER – Thawed En-Route) samples were not included in any of the comparisons. In an attempt to check the applied correction to the 2008-30 data set, frozen deep water samples from a selection of 2008-30 deep stations were removed from their freezer storage and run on the Astoria at IOS on April 8, 2010, by Linda White and Kenny

Scozzzafava. Results from these runs are illustrated in Appendix Figures A15 to A23 and are compared with the original 2008-30 data set, 2008-30 corrected data, and NO_3 samples from the 2009-20 LSSL cruise. As can be seen from these plots, while some frozen samples compare well with 2009-20 & corrected data (Appendix Figures A18, A21, A22, & A23), others fall much lower than what would be expected from any of the compared data sets (Appendix Figures A16, A17, A20). The inconsistent results of these re-run frozen deep water samples show that data from samples stored for two years (Aug 2008 – Apr 2010) cannot be used confidently in comparisons. These plots do, however, serve to reinforce the use of the applied 2008-30 data correction, as corrected 2008-30 data points tend to fall in line with samples collected and analyzed in 2009.

Correcrtions to Other Data
It is recommended that Leg 1 samples (frozen) & Sea Ice samples analyzed onboard during LSSL 2008-30 are corrected for drift.

Appendix Figure List & Captions

Figure A1. All 2008-30 NO_3 data collected and analyzed on the Louis S. St. Laurent (blue filled circles) compared to historical Canada Basin data from 2003-21, 2004-16, 2005-04, & 2006-20.

Figure A2. LSSL 2008-30 deep water NO_3 data analyzed on board (blue filled circles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20) along the western side of the Canada Basin, Stations CB3 to CB11.

Figure A3. LSSL 2008-30 deep water NO_3 data analyzed on board (blue filled circles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20) along the eastern side of the Canada Basin, Stations CB16N to CB29.

Figure A4. LSSL 2008-30 NO_3 daily mid-run standard checks (a) WAKO, (b) KANSO AS, (c) KANSO AT, (d) Deep Sea Water Sample, collected at CABOS from 600m depth. Red solid line indicates expected sample concentration; red hatched lines illustrate standard error of +/- 0.2 mmol/m^3; X-axis indicates date of analysis. Standards presented in panels a, b, & c, exhibit little, if any, relationship between date run and analyzed concentration, suggesting the instrument behaved predictably over the course of the cruise. The deep water CABOS sample, panel d, however, appears to decrease in concentraiton over time, with a relationship characterized by the curve: $y = -0.0341x + 13.104$, and a correlation coefficient of $R^2 = 0.8697$.

Figure A5. Average NO_3 (mmol/m^3) for 2003-2006 over indicated depth intervals:
(a) Upper Panel: Average NO_3 (mmol/m^3) +/- StDev from 1500m – 2000m for each CB Station with a depth greater than 3000m, data from 2003-2006
(b) Middle Panel: Average NO_3 (mmol/m^3) +/- StDev from 2000m – 4000m for each CB Station with a depth greater than 3000m, data from 2003-2006
(c) Lower Panel: Average NO_3 (mmol/m^3) +/- StDev from 1500m – 4000m for each CB Station with a depth greater than 3000m, data from 2003-2006

Figure A6. Average NO_3 (mmol/m^3) +/- StDev at each depth, for each CB Station with a depth greater than 3000m, data from 2003-2006. Black Line: 1500 – 2000m average (hatched black StDev), Pink Line: 2000-4000m average (hatched pink StDev), Dark Red Line: 2000-3000m average (hatched red StDev), and Green Line: 3000-4000m average (hatched green StDev).

Figure A7. LSSL 2008-30 calibration and check standards run for each of the three nutrient parameters over the course of the cruise. As virtually all plots of the standard runs show little deviation over the course of the cruise, instead of showing plots here, details on the average, standard deviation, maximum, minimum, slope (with respect to day run) and correlation coefficient (with respect to day run) are listed at the bottom of the table.

Figure A8. As in Figure A2, 2008-30 NO_3 deep water samples (only stations deeper than >3000m) analyzed on board (blue filled circles) & Corrected NO_3 data (red triangles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20) along the western side of the Canada Basin, Stations CB3 to CB11.

Figure A9. Depth profile (250m – 4000m) of Figure A7: 2008-30 NO_3 deep water samples analyzed on board (blue filled circles) & Corrected NO_3 data (red triangles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20) along the western side of the Canada Basin, Stations CB3 to CB11.

Figure A10. As in Figure A3, 2008-30 NO_3 deep water samples (only stations deeper than >3000m) analyzed on board (blue filled circles) & Corrected NO_3 data (red triangles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20) along the eastern side of the Canada Basin, Stations CB16N to CB29.

Figure A11. Depth profile (250m – 4000m) of Figure A9: 2008-30 NO_3 deep water samples analyzed on board (blue filled circles) & Corrected NO_3 data (red triangles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20) along the eastern side of the Canada Basin, Stations CB16N to CB29.

Figure A12. Example Profile: South Western Canada Basin Station CB5 depth profile, 250 – 4000m, 2008-30 NO_3 data analyzed on board (blue filled circles) & Corrected NO_3 data (red triangles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20).

Figure A13. Example Profile: North Western Canada Basin Station CB9 depth profile, 250 – 4000m, 2008-30 NO_3 data analyzed on board (blue filled circles) & Corrected NO_3 data (red triangles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20).

Figure A14. Example Profile: North Eastern Canada Basin Station CB15 depth profile, 250 – 4000m, 2008-30 NO_3 data analyzed on board (blue filled circles) & Corrected NO_3 data (red triangles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20).

Figure A15. Example Profile: South Eastern Canada Basin Station CB21 depth profile, 250 – 4000m, 2008-30 NO_3 data analyzed on board (blue filled circles) & Corrected NO_3 data (red triangles) compared with historical data (2003-21, 2004-16, 2005-04, & 2006-20).

Figure A16. All 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010 (by Linda White & Kenny Scozzafava). 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

Figure A17. CB4: 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010. 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

Figure A18. CB8: 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010. 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

Figure A19. CB9: 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010. 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

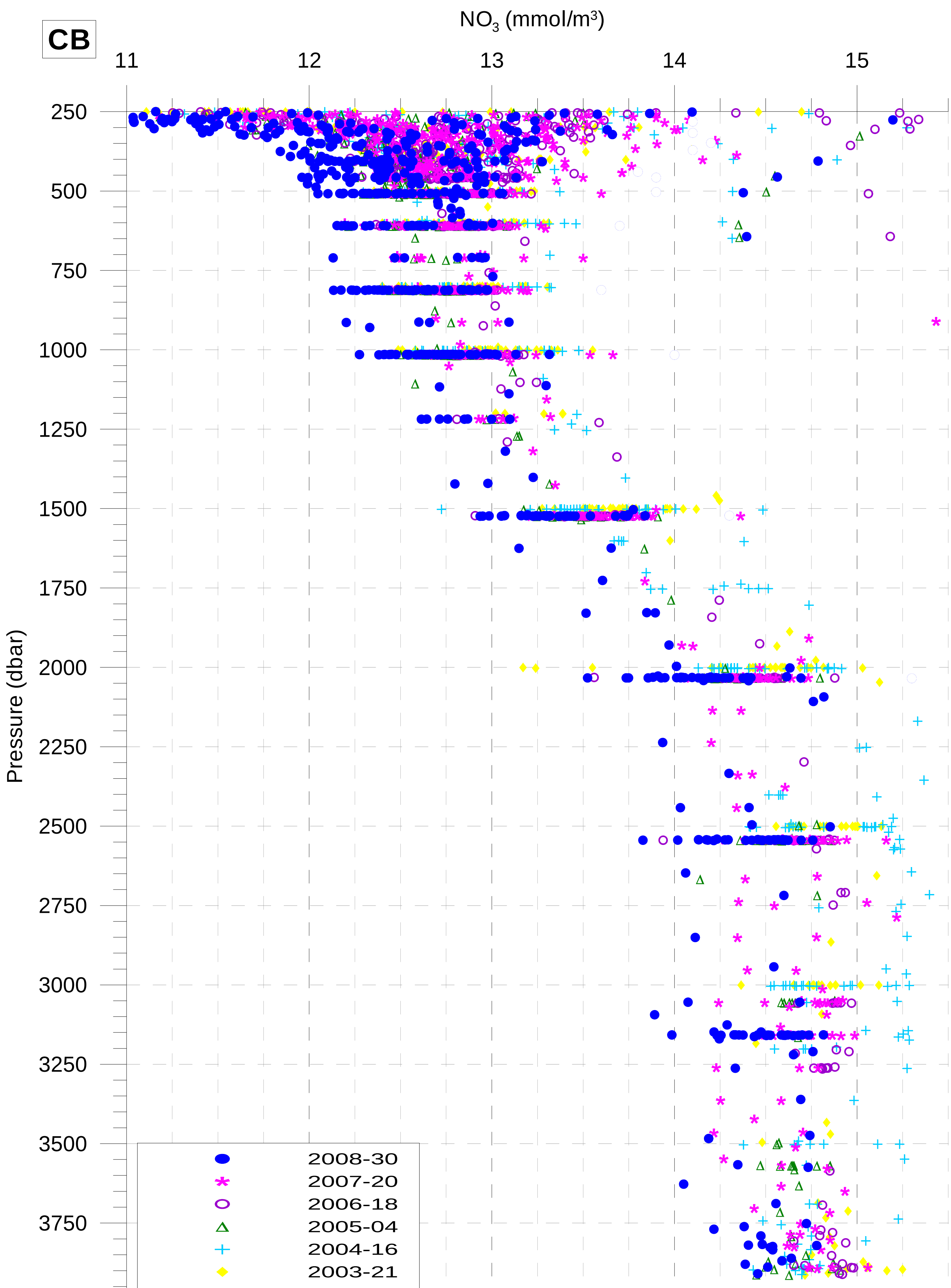
Figure A20. CB17: 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010. 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

Figure A21. NE1: 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010. 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

Figure A22. PP5: 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010. 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

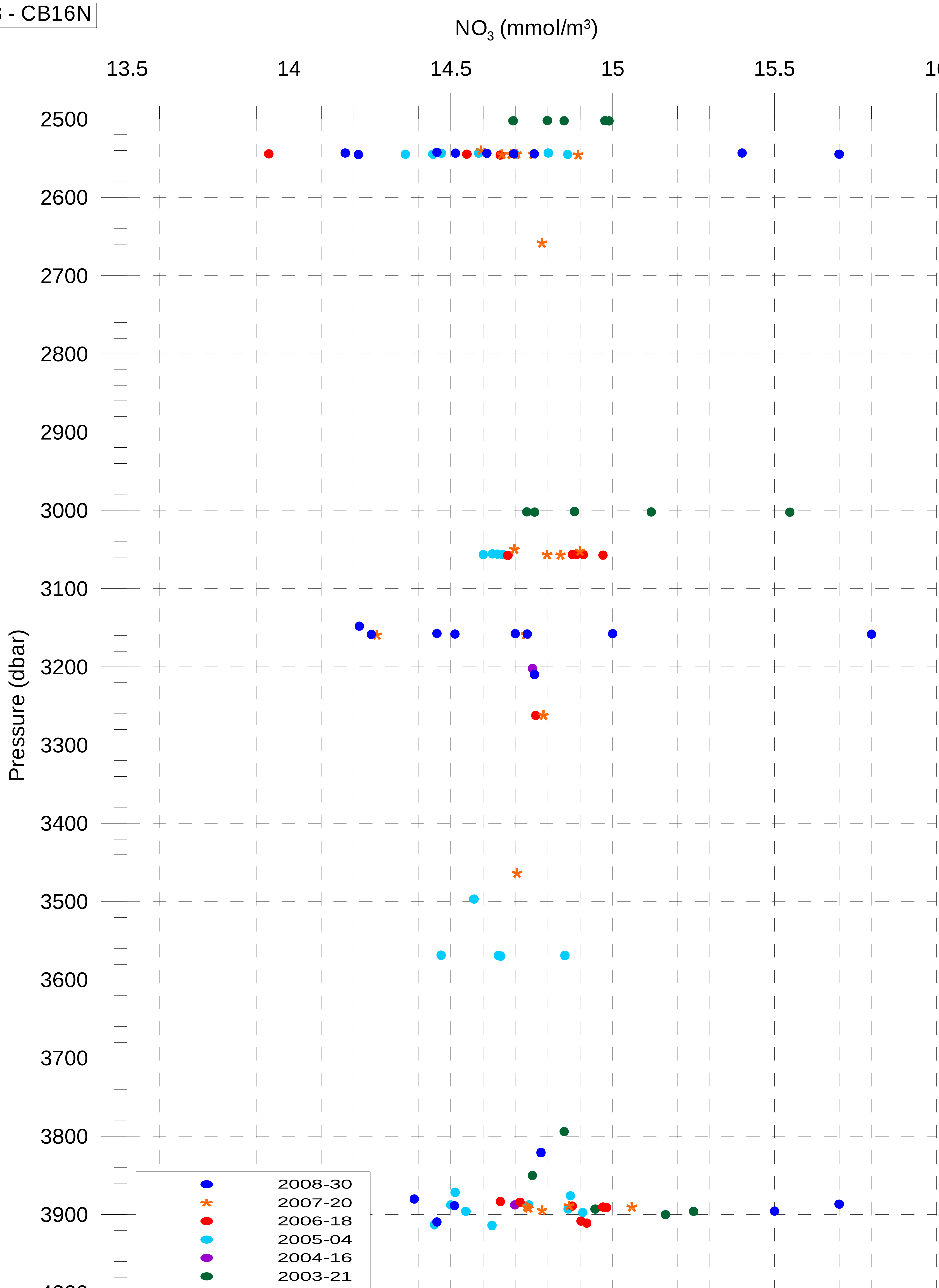
Figure A23. PP6: 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010. 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

Figure A24. PP7: 2008-30 NO_3 data analyzed on board (blue filled circles) and corrected NO_3 values (red filled circles), compared with 2008-30 frozen samples (green filled circles) analyzed at IOS on the Astoria, April 8, 2010. 2009-20 NO_3 data analyzed on board included for comparison (brown filled squares).

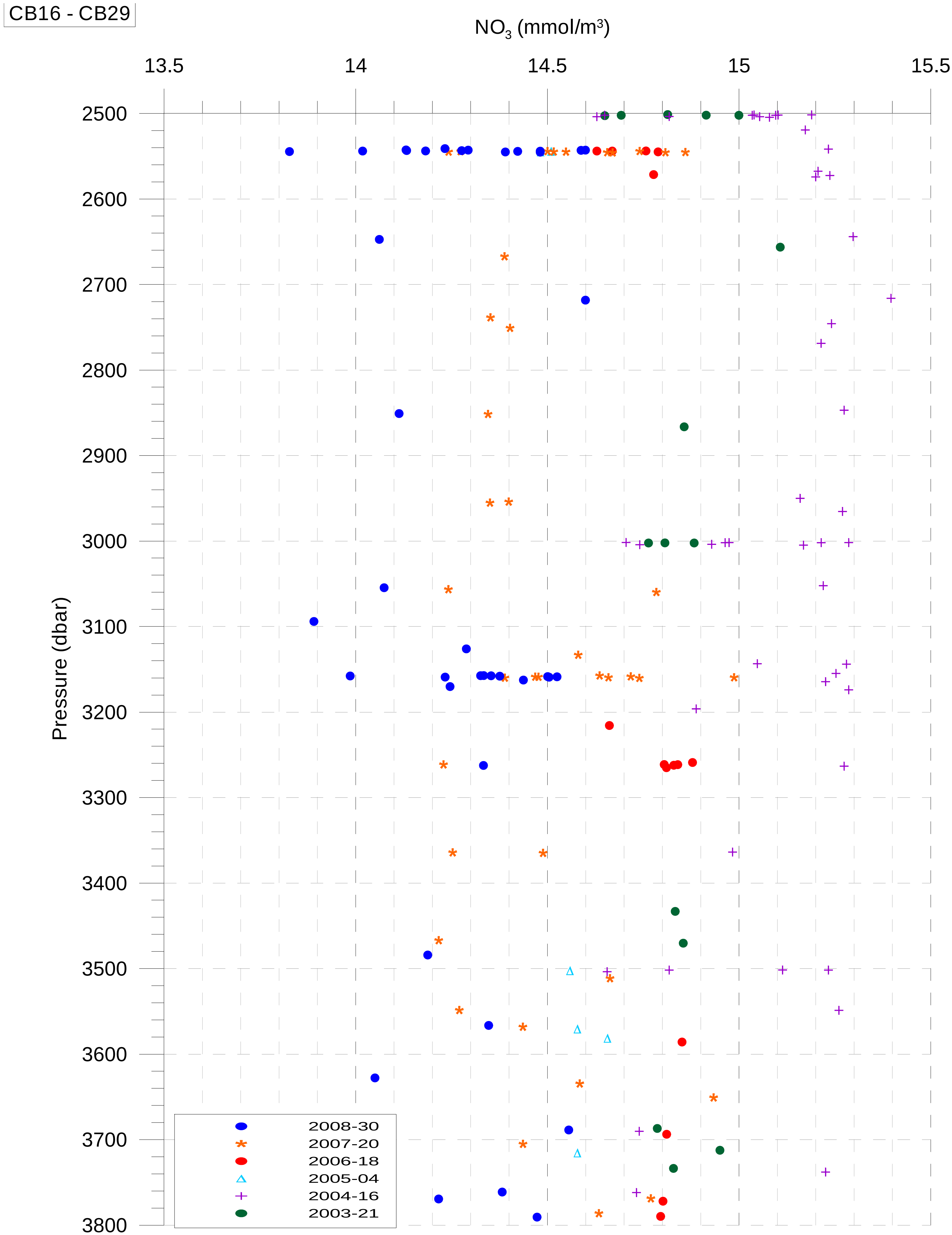


Appendix Figure A1

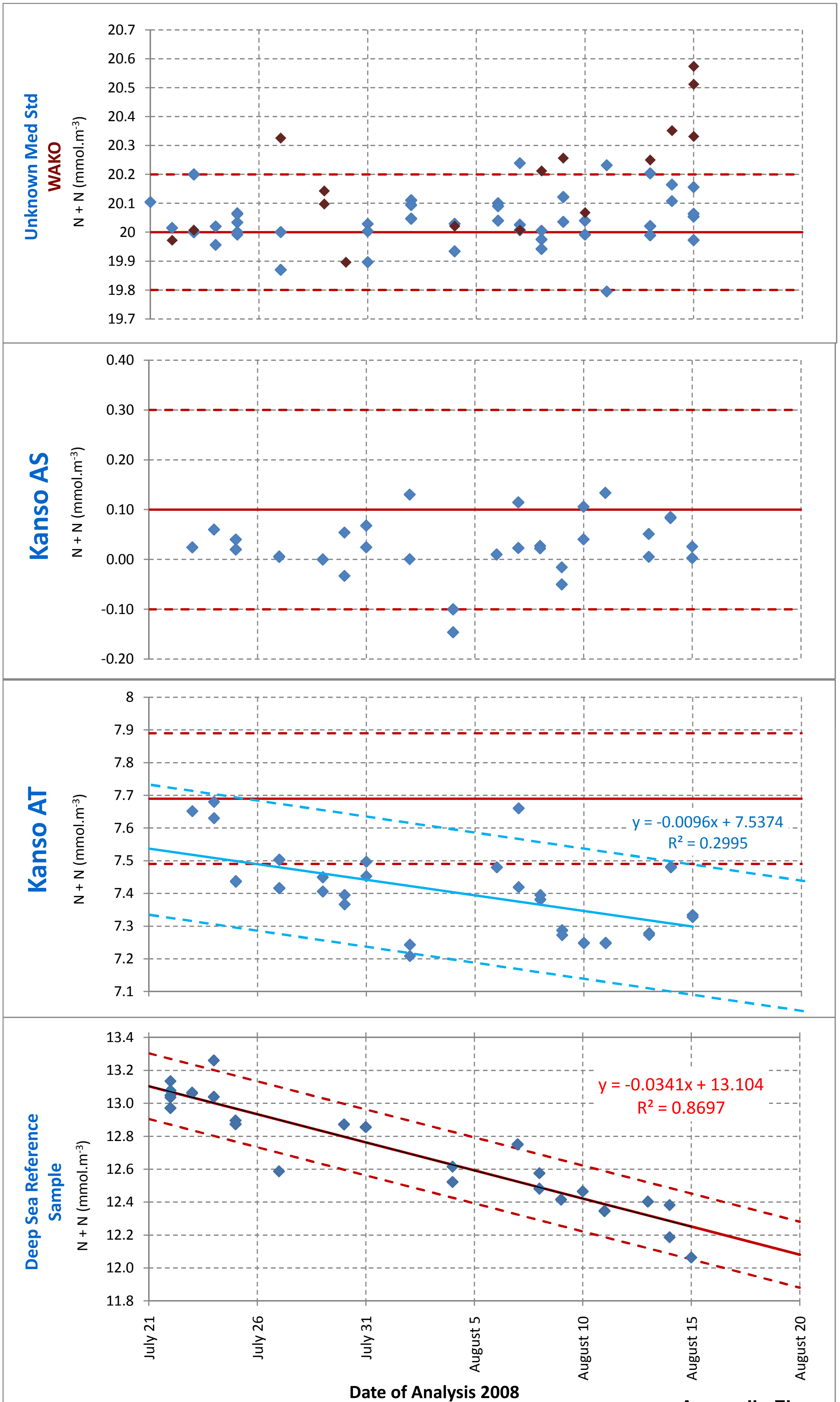
CB3 - CB16N



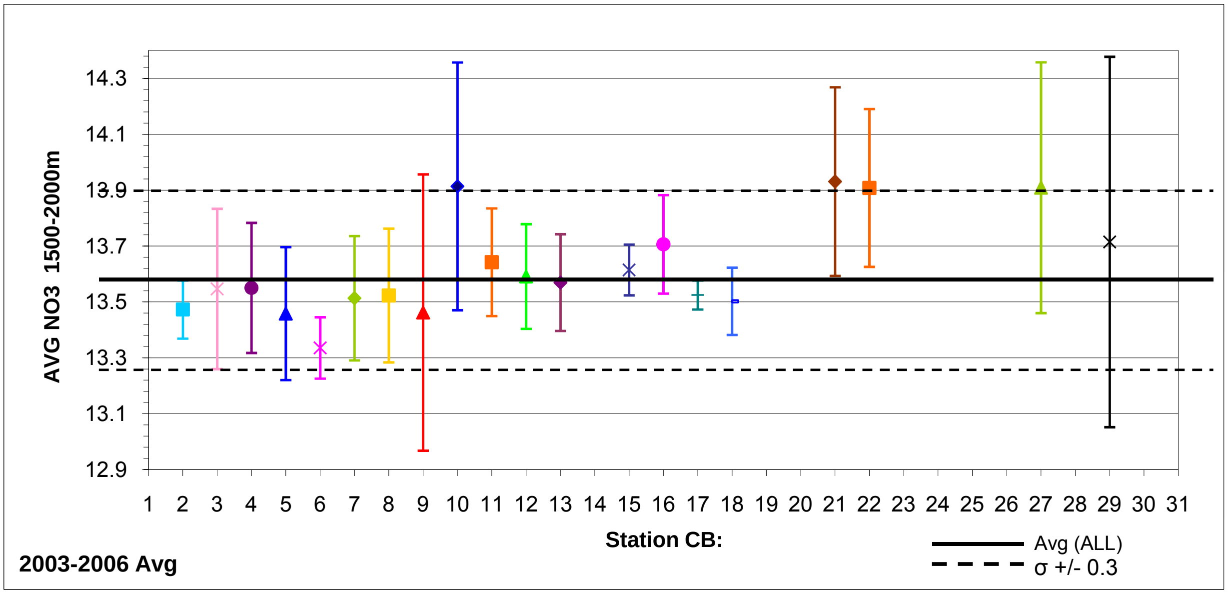
Appendix Figure A2

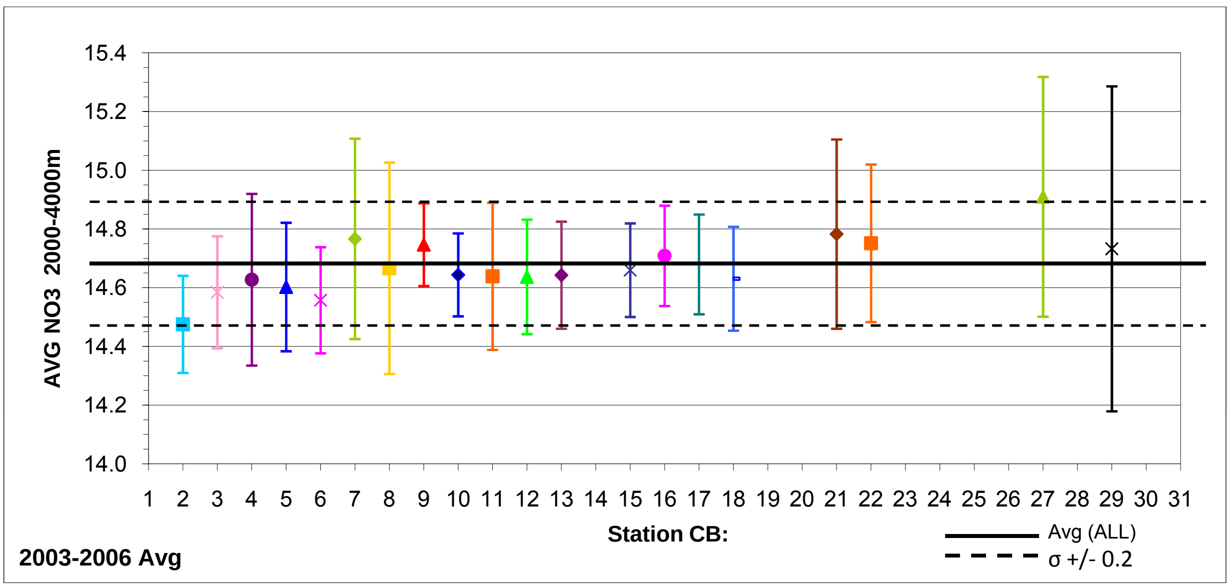


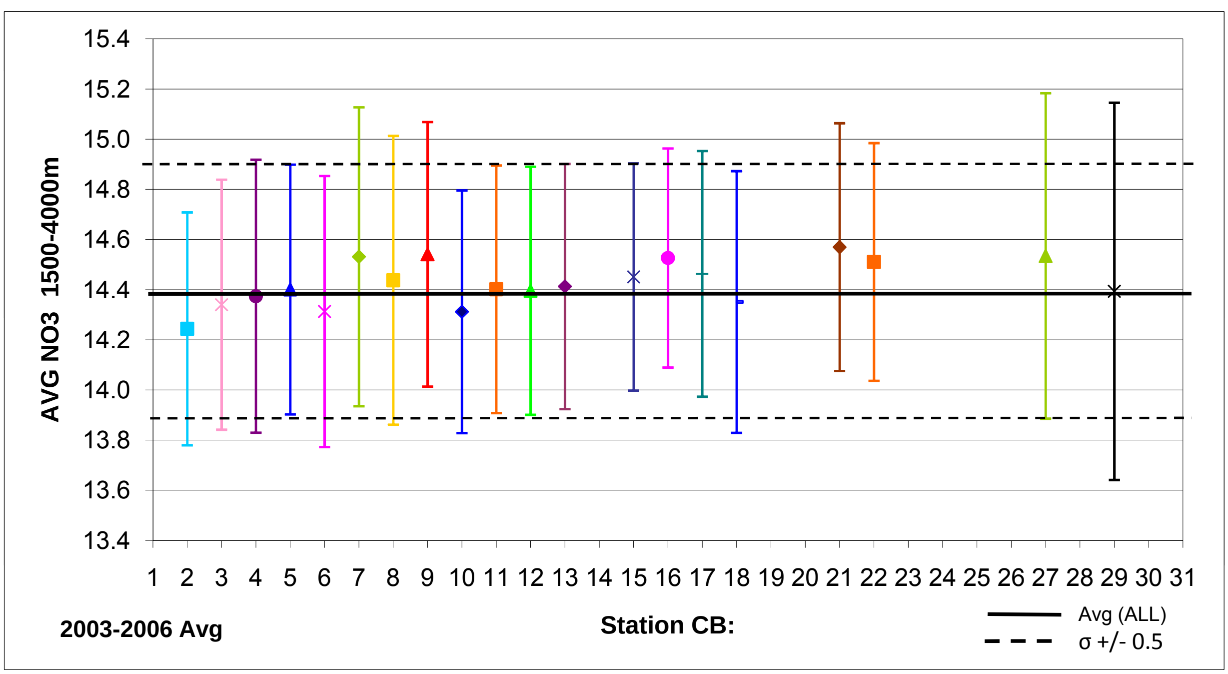
Appendix Figure A3



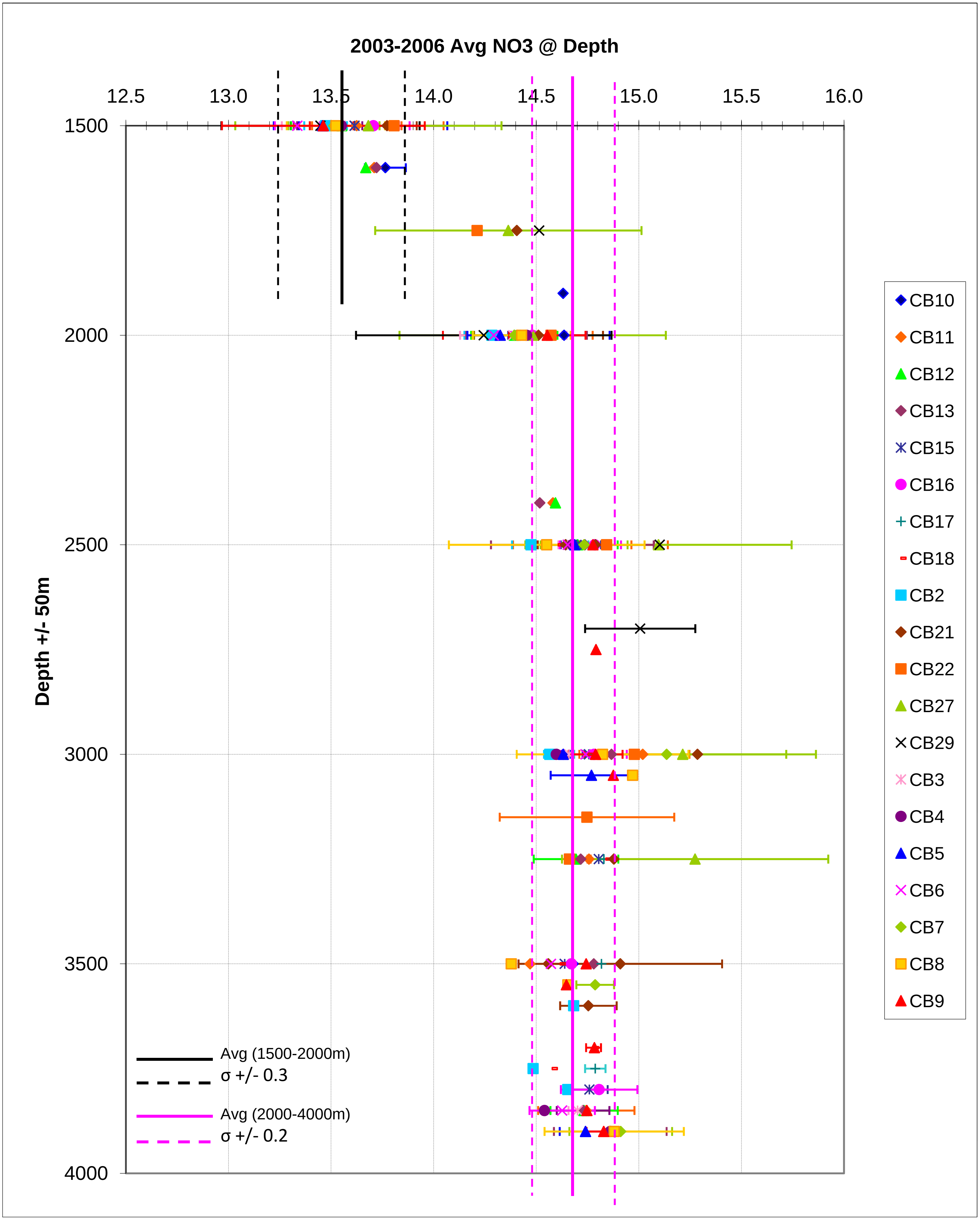
Appendix Figure A4







Appendix Figure A5

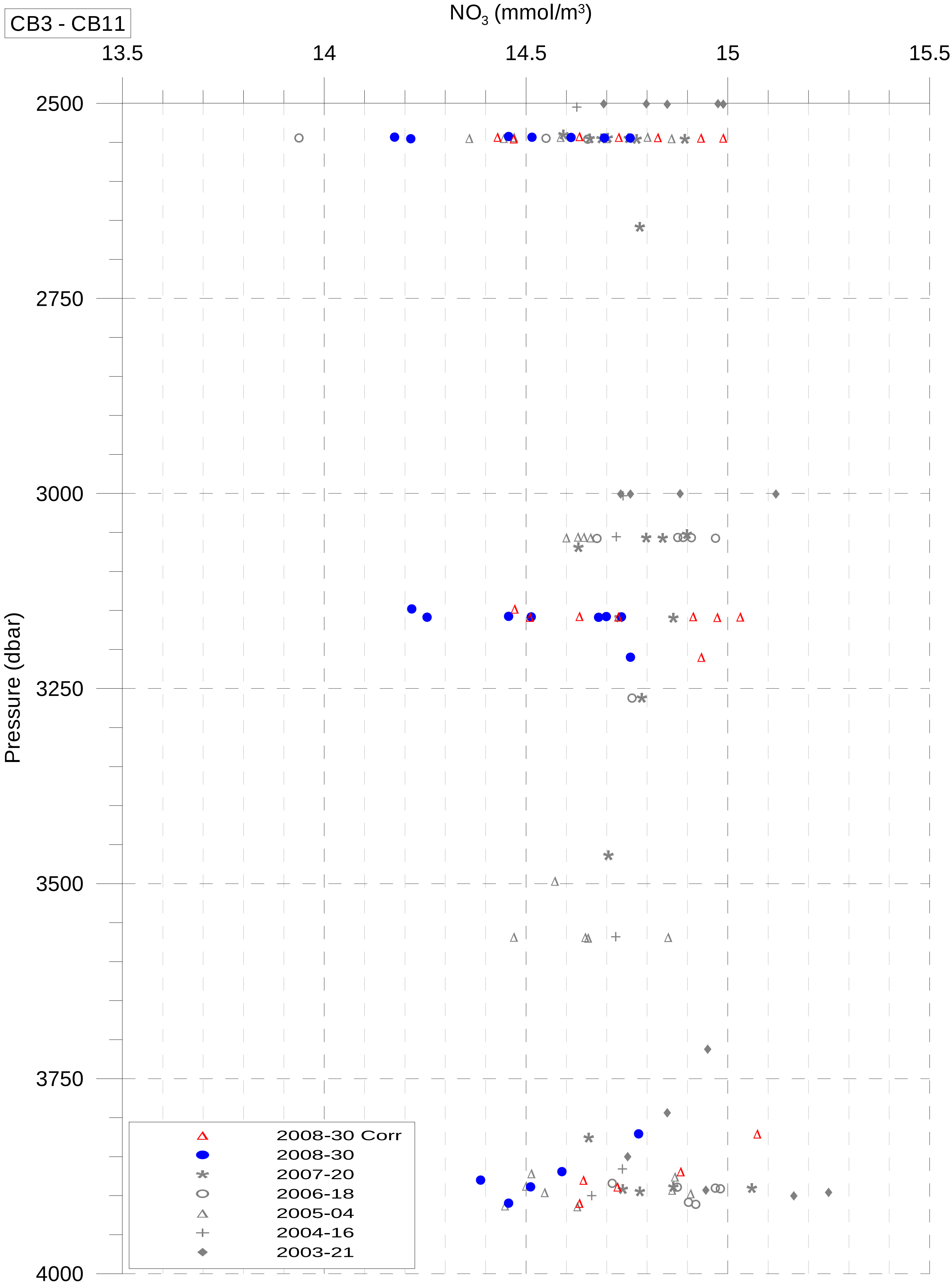


Appendix Figure A6

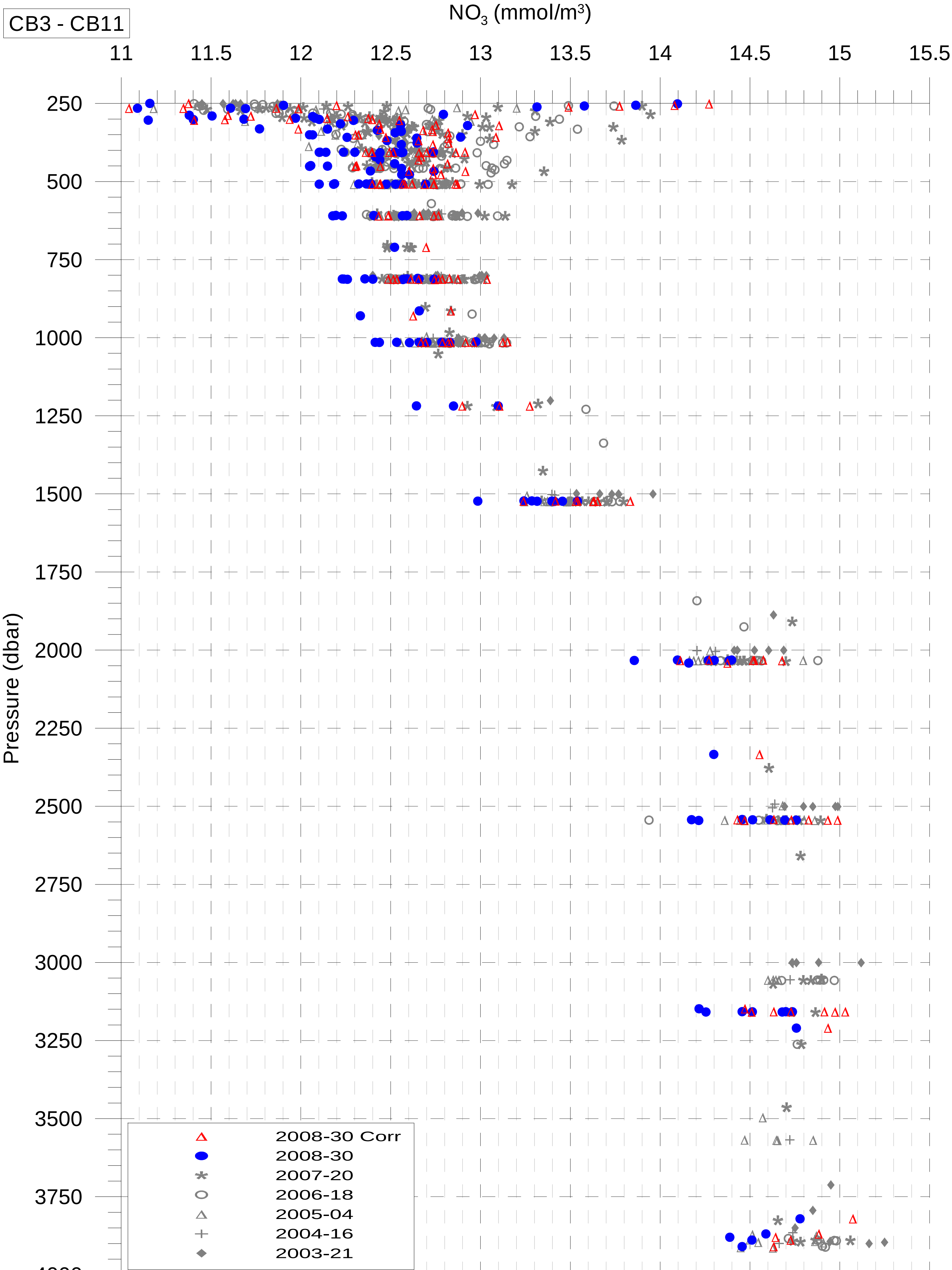
LSSL 2008-30 Standard Runs NO3, SiO4, PO4

Date	DAY	Unknown Medium Standard NO3 +NO2 20.0µm/l	Deep Sea Reference Sample NO3 +NO2 µm/l	Wako Nitrate 20 µm/l	AY N Nitrate 5.7 um/l	BA N Nitrate 0.02 um/l	AX N Nitrate 21.9 um/l	AS N Nitrate 0.10 um/l	AT N Nitrate 7.69 um/l	AU N Nitrate 30.67 um/l	Unknown Medium Standard Si 40.0µm/l	Deep Sea Reference Sample Si µm/l	Wako Silicate 50 µm/l	AY Si Silicate 30.8 um/l	BA Si Silicate 1.7 um/l	AX Si Silicate 56.09 um/l	AS Si Silicate 1.70 um/l	AT Si Silicate 18.41 um/l	AU Si Silicate 68.22 um/l	Unknown Medium Standard PO4 2.00µm/l	Deep Sea Reference Sample PO4 µm/l	Ay P Phosphate 0.51 um/l	BA P Phosphate 0.08 um/l	AX P Phosphate 1.63 um/l	As P Phosphate 0.08 um/l	AT P Phosphate 0.59 um/l	Au P Phosphate 2.23 um/l
Expected Value		20.0		20.0	5.7	0.02	21.9	0.10	7.69	30.67	40.0		50.0	30.8	1.7	56.1	1.70	18.41	68.22	2.00		0.51	0.08	1.63	0.08	0.59	2.23
21-Jul-08	0				6.2									30.6								0.51					
21-Jul-08	0				6.2									30.6								0.51					
21-Jul-08	0	20.1									40.0									2.01							
22-Jul-08	1	20.0	13.0	20.0	6.3						40.0	7.7	50.1	30.4						2.01	0.95	0.54					
22-Jul-08	1		13.0		6.3							7.8		30.2							0.94	0.54					
22-Jul-08	1		13.0		6.2							7.8		30.5							0.93	0.54					
22-Jul-08	1		13.1									8.0									0.94						
22-Jul-08	1		13.1									7.9									0.94						
23-Jul-08	2	20.2	13.1	20.0	6.2						40.1	7.9	50.1	30.3						2.00	0.93	0.53					
23-Jul-08	2	20.0	13.1		6.2						40.4	7.8		30.9						2.00	0.93	0.53					
23-Jul-08	2				6.2			0.0	7.7	30.7				30.6			1.8	18.9	69.6						0.06	0.59	
24-Jul-08	3	20.0	13.0		6.3			0.1	7.6	29.9	40.0	8.0		30.6				18.8		1.98	0.94	0.55				0.59	
24-Jul-08	3	20.0	13.3		6.4			0.1	7.7	30.3		7.9		32.7				19.1		2.00	0.92	0.56			0.06	0.61	
24-Jul-08	3				6.4									30.6								0.55					
25-Jul-08	4	20.0	12.9		6.2						40.0	7.8	50.3	30.4								0.55					
25-Jul-08	4	20.0	12.9			0.0					40.1	7.9			1.8												
25-Jul-08	4	20.1				0.0		0.0	7.4	30.7	39.9				1.8		1.9	18.3	69.0								
25-Jul-08	4	20.0						0.0	7.4	30.8	40.2						1.8	18.5	68.7								
25-Jul-08	4	20.1																									
26-Jul-08	5																			1.98	0.90						
26-Jul-08	5																			1.98			0.05		0.05	0.59	
26-Jul-08	5																						0.05		0.05	0.60	2.24
27-Jul-08	6	20.0	12.6	20.3																2.00	0.88						
27-Jul-08	6	19.9				0.0		0.0	7.4	30.4										1.98			0.05		0.06	0.60	2.26
27-Jul-08	6					0.0		0.0	7.5	30.4													0.05		0.07	0.60	2.27
28-Jul-08	7										40.2	8.1	50.4														
28-Jul-08	7										40.2				1.8			18.5	68.7								
28-Jul-08	7														1.7		1.8	18.5	69.2								
29-Jul-08	8			20.1		-0.1		0.0	7.4	30.5	40.2		50.3		1.7		1.8	18.5	68.3	2.01	0.89		0.06		0.06	0.59	2.24
29-Jul-08	8			20.1		-0.1		0.0	7.4	30.6	40.4				1.7		1.7	18.4	68.6				0.05		0.05	0.59	2.25
30-Jul-08	9		12.9	19.9		0.0					40.2		50.3		1.7					2.00	0.89						
30-Jul-08	9						21.9	0.1	7.4	30.2						59.7	1.6	18.5	67.5					1.67	0.06	0.60	2.25
30-Jul-08	9						22.0	0.0	7.4	30.1						59.6	1.7	18.4	67.4					1.67	0.06	0.60	2.25
31-Jul-08	10	19.9	12.9									8.7	50.0								0.88						
31-Jul-08	10	20.0					22.0	0.1	7.5	30.3		8.6				60.1	1.8	18.2	68.1					1.68	0.07	0.61	2.27
31-Jul-08	10	20.0					22.0	0.0	7.5	30.3	40.0					59.4	1.8	18.1	68.7	2.01				1.68	0.06	0.61	2.26
31-Jul-08	10																										
02-Aug-08	12	20.1									40.0									1.99							
02-Aug-08	12	20.1					21.8	0.1	7.2	30.0	40.0					59.1	1.7	18.2	67.8	2.00				1.66	0.06	0.59	2.24
02-Aug-08	12	20.0					21.9	0.0	7.2	30.1	40.0					59.4	1.6	18.2	67.5	2.00				1.66	0.05	0.58	2.25
04-Aug-08	14			20.0									50.1														
04-Aug-08	14	19.9	12.5				21.9	-0.1			39.9	8.6				59.9	1.7			2.00	0.86			1.67	0.06		
04-Aug-08	14	20.0	12.6				22.0	-0.1			40.0	8.7				60.2	1.7			2.01	0.85			1.67	0.06		
06-Aug-08	16	20.1					22.3	0.0		30.6	39.8					60.2	1.7		68.7	1.99				1.67	0.06		2.25
06-Aug-08	16	20.1					22.2	0.0	7.48	30.8	40.0					60.6	1.7	18.2	68.3	2.00				1.68	0.07	0.61	2.26
06-Aug-08	16	20.0									40.0									1.99							
07-Aug-08	17	20.2	12.8	20.0							40.0	9.0	49.3							1.96	0.90						
07-Aug-08	17	20.0					21.8	0.1	7.7	30.0	40.0					59.0	1.9	18.5	67.5	2.01	0.86			1.65	0.04	0.58	2.23
07-Aug-08	17	20.0						0.0	7.4	30.2	40.2						1.9	18.2	67.5	1.99					0.04	0.59	2.25
07-Aug-08	17																										
08-Aug-08	18	20.0	12.5	20.2							40.0		50.2							2.00	0.86						
08-Aug-08	18	20.0	12.6					0.0	7.4	30.2	39.9	8.7					1.7	18.6	67.8	2.00	0.86				0.07	0.60	2.25
08-Aug-08	18							0.0	7.4	30.3							1.7	18.4	67.7						0.06	0.59	2.25
08-Aug-08	18	19.9									39.9									2.00							
09-Aug-08	19	20.1	12.4	20.3				0.0	7.3	30.1	40.1	8.7	50.3				1.7	18.5	69.1	2.00	0.84				0.06	0.58	2.24
09-Aug-08	19	20.0						-0.1	7.3	30.1	40.1						1.7	18.3	68.0	1.99					0.06	0.57	2.23
10-Aug-08	20	20.0	12.5	20.1				0.1	7.2	30.2	39.8	8.8	50.2				1.7	18.4	67.1	2.00	0.88				0.06	0.57	2.25
10-Aug-08	20	20.0						0.0	7.2	30.3	39.9						1.7	18.3	67.1	1.99					0.07	0.59	2.26
11-Aug-08	21	20.2	12.3								40.1	8.9								2.01	0.84						
11-Aug-08	21	19.8						0.1	7.2		40.1						1.9	18.5		2.00					0.06	0.59	
11-Aug-08	21							0.1	7.2								1.8	18.4							0.07	0.59	
13-Aug-08	23	20.0	12.4	20.3							40.0	8.7	50.3							2.01	0.88						
13-Aug-08	23	20.0						0.1	7.3	29.8	40.1						1.7	18.3	68.8	2.00					0.07	0.60	2.26
13-Aug-08	23	20.2						0.0	7.3	29.9	39.9						1.7	18.3	69.8	2.00					0.06	0.61	2.26
14-Aug-08	24	20.2	12.4	20.4							40.1	8.8	50.1							2.00	0.83						
14-Aug-08	24	20.1	12.2					0.1	7.5	30.9	40.1	8.7					1.7	18.7	68.4	2.00	0.85				0.08	0.60	2.27
14-Aug-08	24							0.1	7.5	30.5							1.8	18.6	68.4						0.07	0.60	2.24
15-Aug-08	25	20.0	12.1	20.3							40.0	8.8	49.9							1.99	0.84						
15-Aug-08	25	20.2		20.6				0.0	7.3	30.3	39.9		50.3				1.8	18.2	67.3	1.95	0.83				0.08	0.59	2.27
15-Aug-08	25	20.1		20.5				0.0	7.3	30.0			50.0				1.8	18.2	67.3	1.99					0.07	0.61	2.25
15-Aug-08	25	20.1																									
Expected Value		***20.0***		***20.0***	***5.7***	***0.02***	***21.9***	***0.10***	***7.69***	***30.67***	***40.0***		***50.0***	***30.8***	***1.7***	***56.1***	***1.70***	***18.41***	***68.22***	***2.00***		***0.51***	***0.08***	***1.63***	***0.08***	***0.59***	***2.23***
Average Measurement		20.04	12.73	20.19	6.27	0.00	21.99	0.03	7.40	30.31	40.03	8.33	50.13	30.68	1.73	59.75	1.75	18.43	68.20	2.00	0.89	0.54	0.05	1.67	0.06	0.59	2.25
n		45	26	16	12	7	11	35	32	31	42	25	17	12	7	11	32	32	29	41	28	11	6	11	34	32	27
StDev		0.09	0.33	0.20	0.07	0.04	0.14	0.06	0.13	0.29	0.13	0.45	0.25	0.66	0.06	0.49	0.08	0.22	0.75	0.01	0.04	0.02	0.00	0.01	0.01	0.01	0.01
Diff (Avg - Expected)		0.04		0.19	0.57	-0.02	0.09	-0.07	-0.29	-0.36	0.03		0.13	-0.12	0.03	3.66	0.05	0.02	-0.02	0.00		0.03	-0.03	0.04	-0.02	0.00	0.02
Max		20.24	13.26	20.57	6.40	0.04	22.25	0.13	7.68	30.94	40.35	9.00	50.43	32.69	1.82	60.62	1.94	19.10	69.84	2.01	0.95	0.56	0.06	1.68	0.08	0.61	2.27
Min		19.79	12.06	19.90	6.19	-0.05	21.79	-0.15	7.21	29.80	39.78	7.74	49.27	30.19	1.65	59.04	1.61	18.07	67.05	1.95	0.83	0.51	0.05	1.65	0.04	0.57	2.23
Slope		0.002	-0.034	0.016	0.015	-0.016	0.010	0.001	-0.010	-0.010	-0.007	0.046	-0.004	0.146	-0.024	0.037	-0.001	-0.009	-0.034	0.000	-0.004	0.010	0.002	-0.001	0.001	0.000	0.000
R2		0.026	0.870	0.456	0.077	0.578	0.043	0.024	0.299	0.062	0.142	0.837	0.018	0.079	0.578	0.049	0.004	0.101	0.100	0.011	0.808	0.667	0.422	0.057	0.154	0.024	0.007

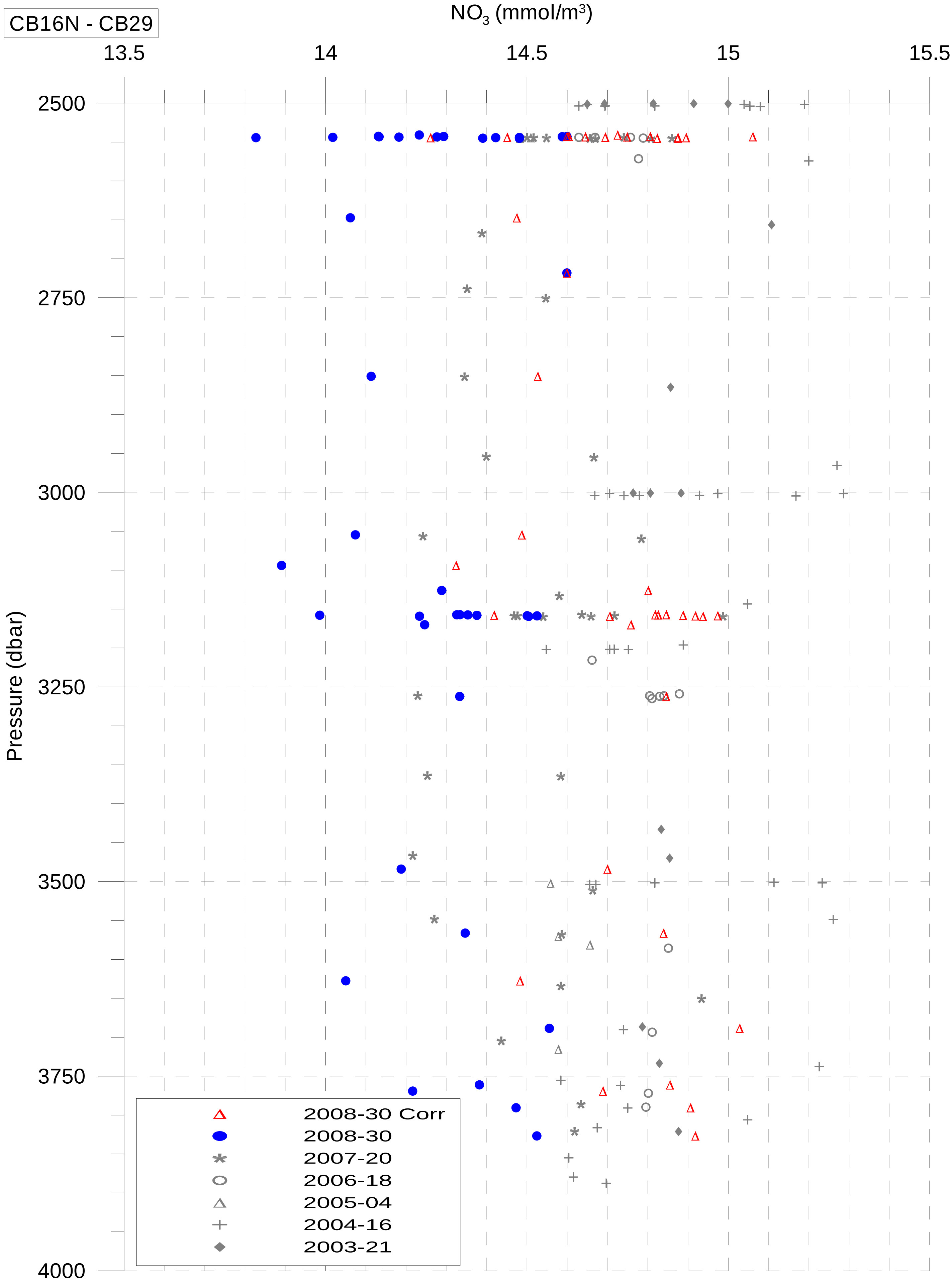
Appendix Figure A7



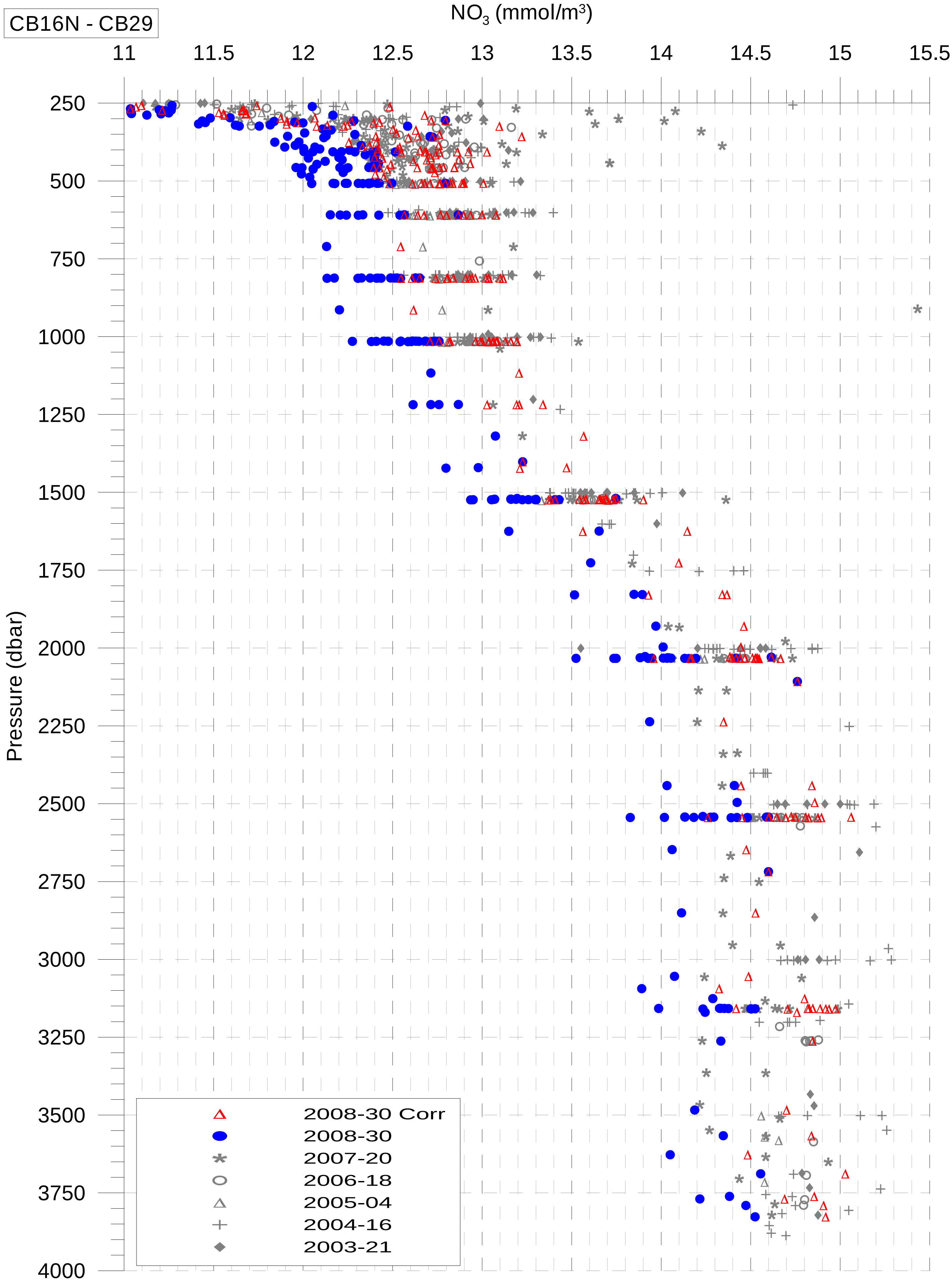
Appendix Figure A8



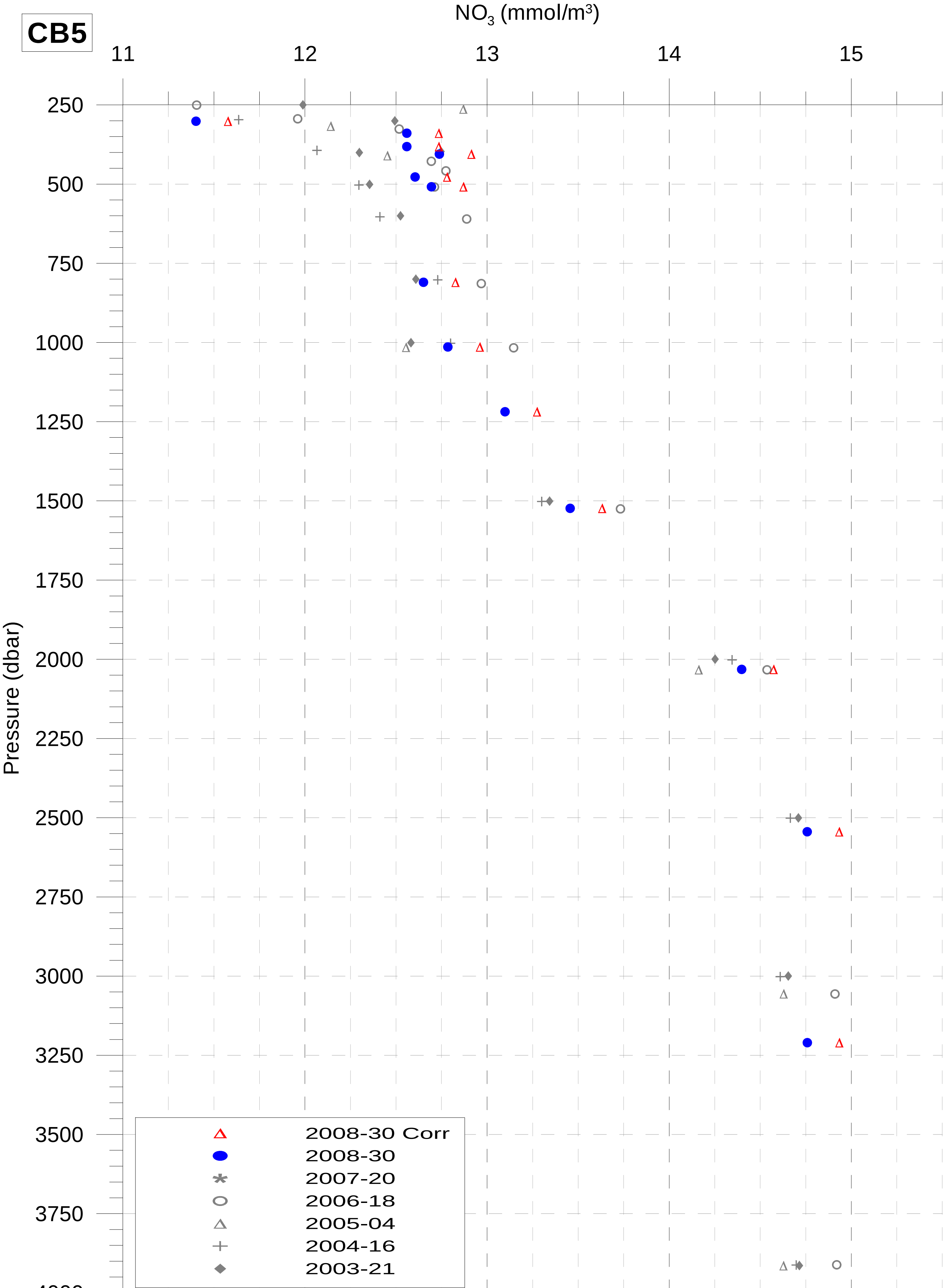
Appendix Figure A9



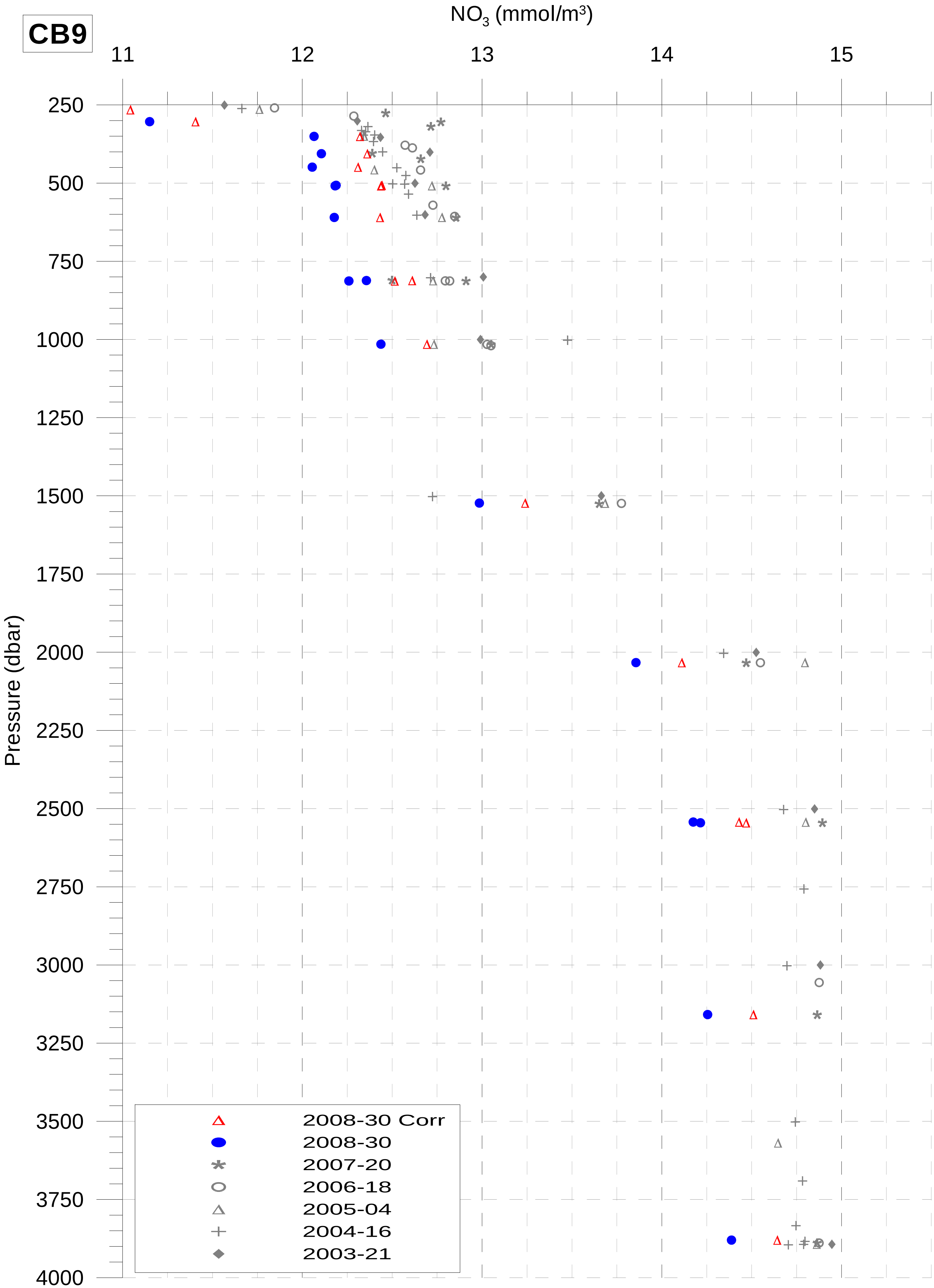
Appendix Figure A10



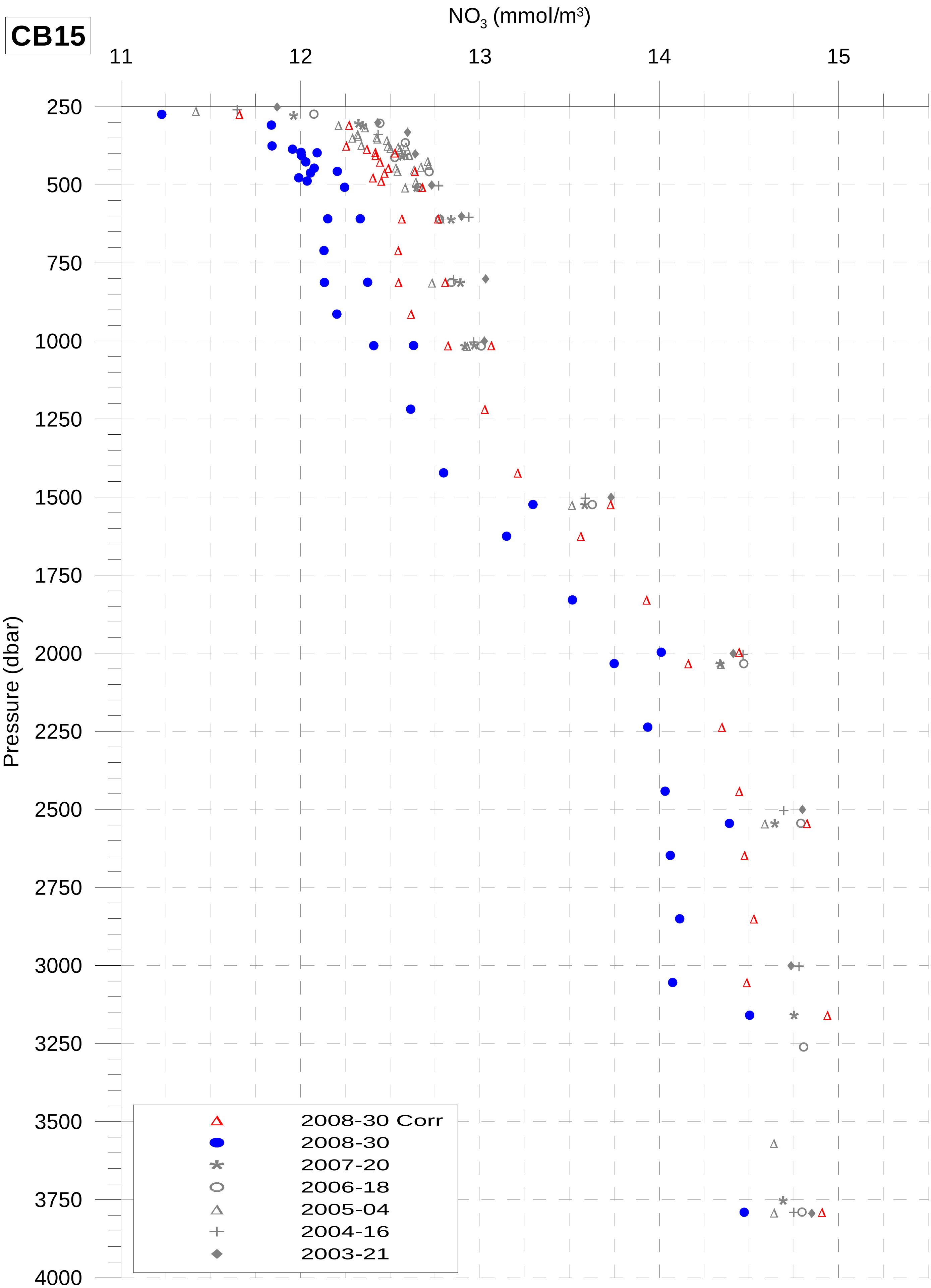
Appendix Figure A11



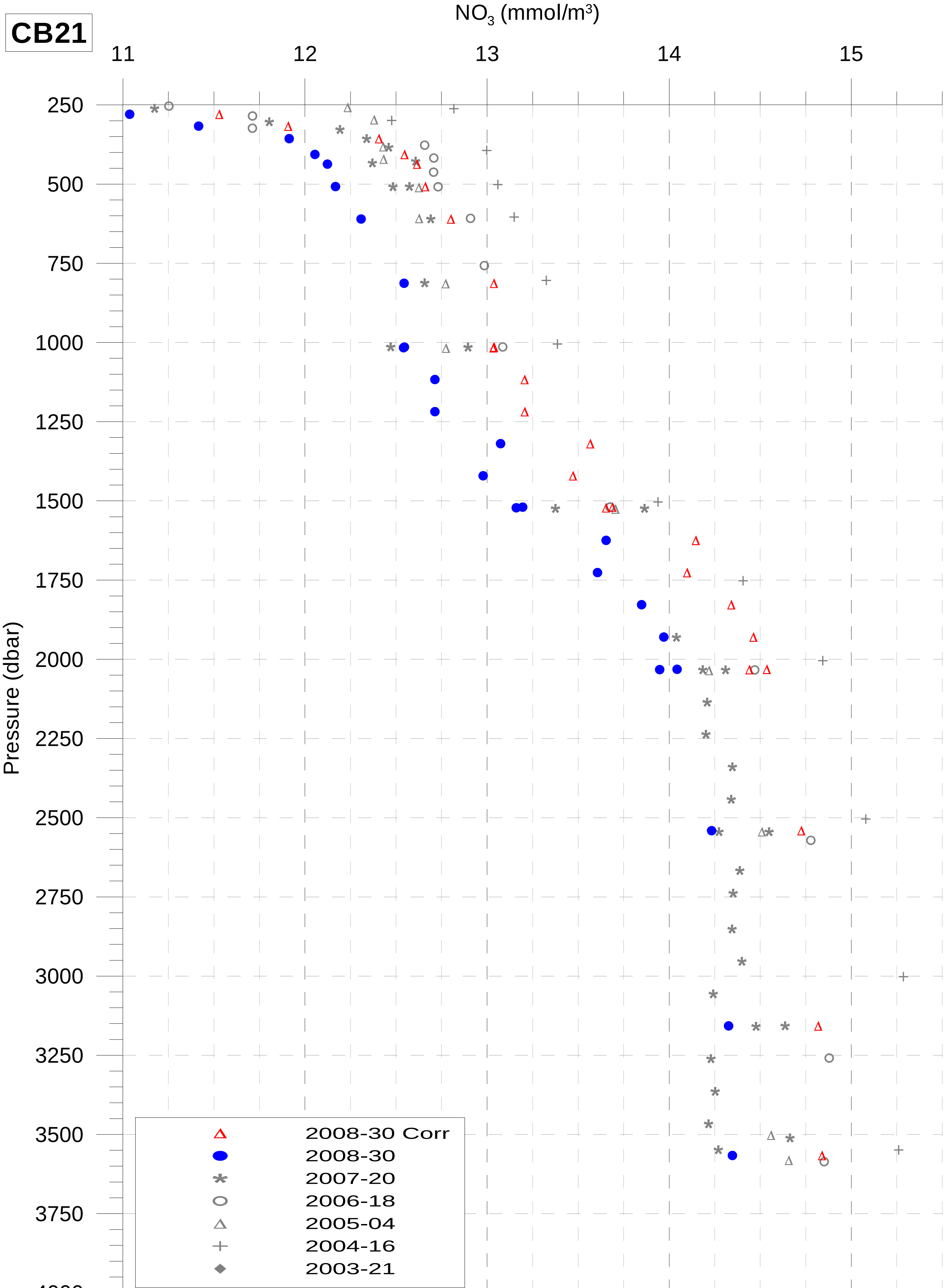
Appendix Figure A12



Appendix Figure A13

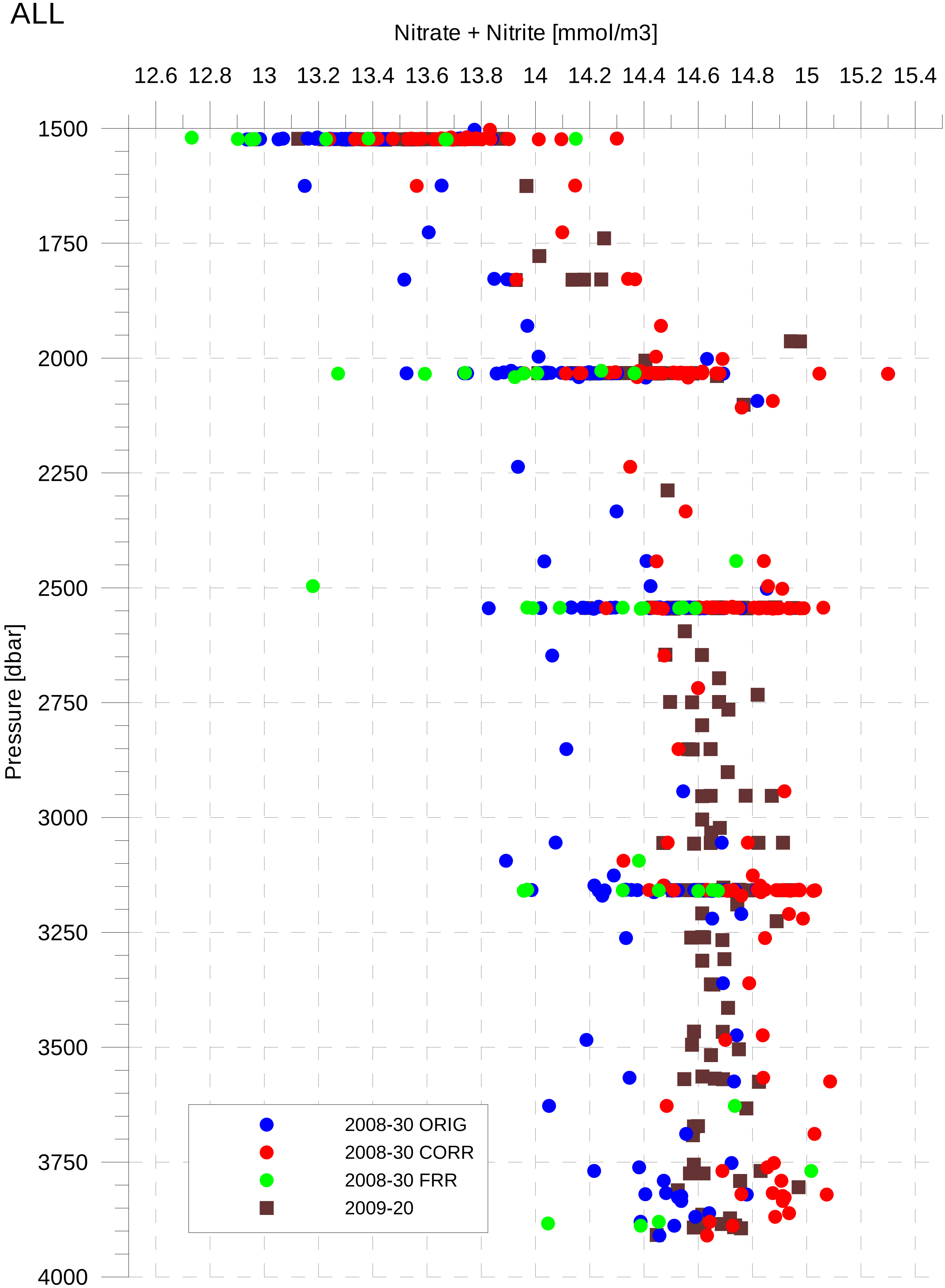


Appendix Figure A14



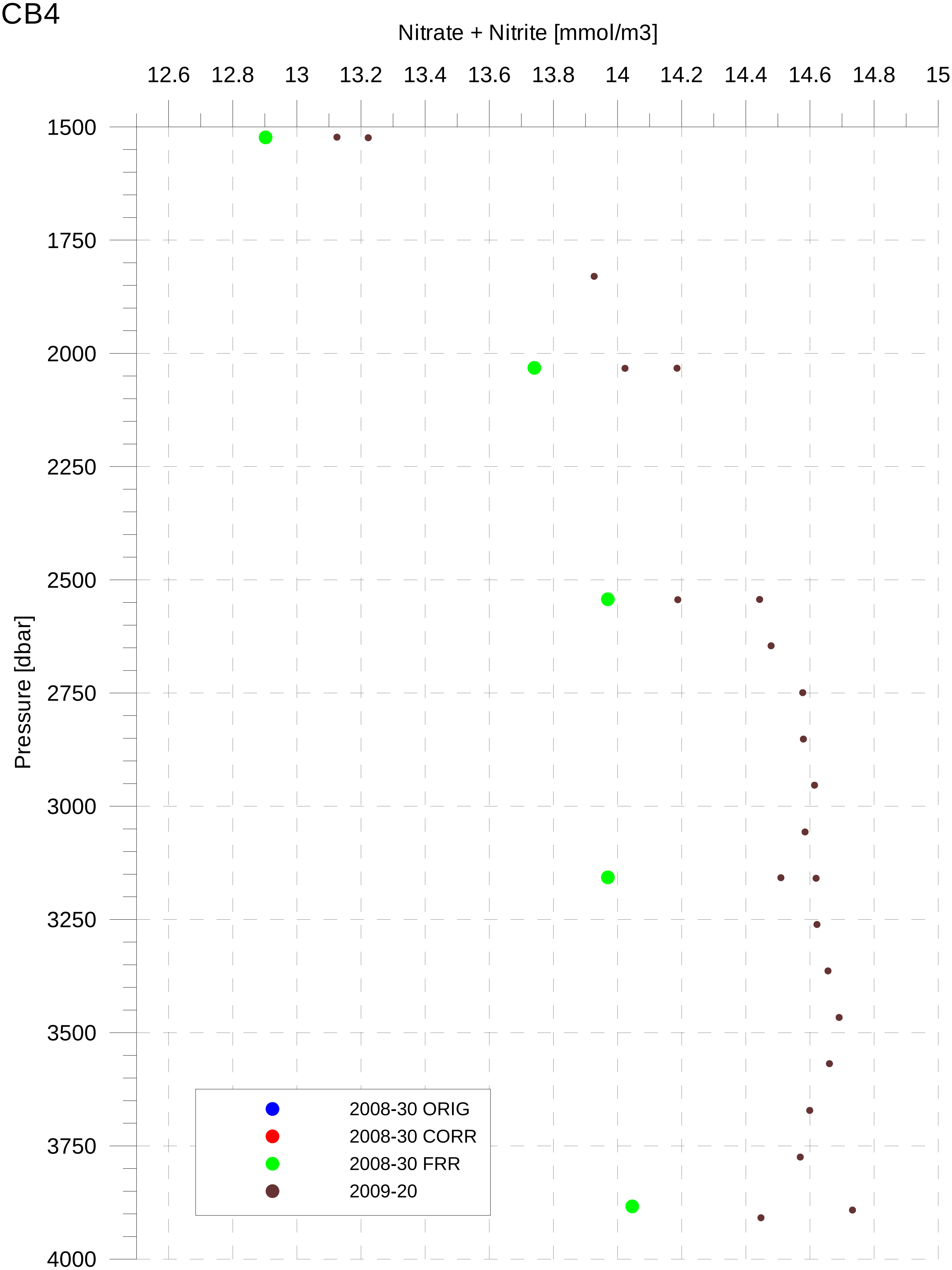
Appendix Figure A15

ALL



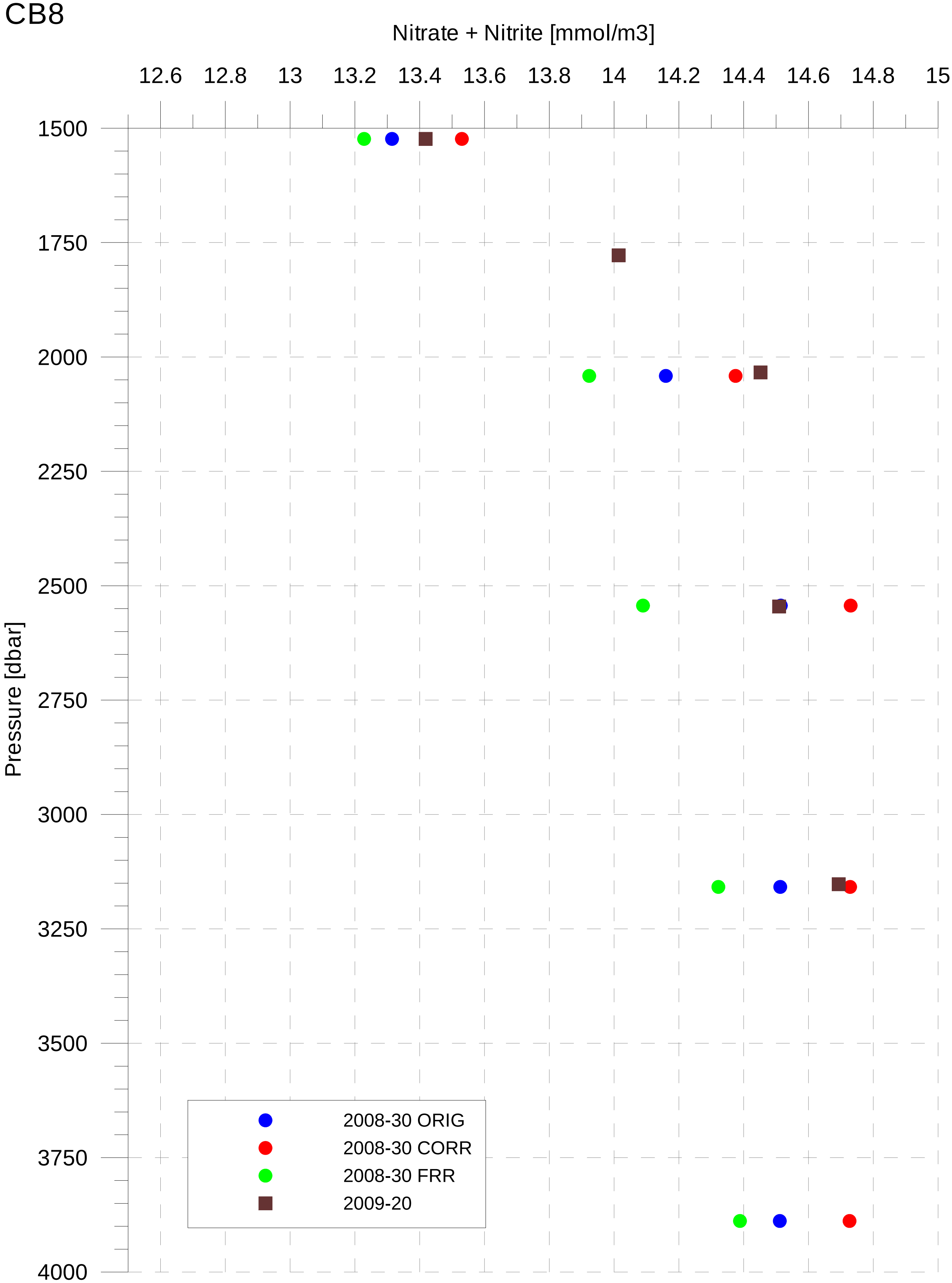
Nitrate + Nitrite [mmol/m3]
12.6 12.8 13 13.2 13.4 13.6 13.8 14 14.2 14.4 14.6 14.8 15 15.2 15.4
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
4000
Pressure [dbar]
2008-30 ORIG
2008-30 CORR
2008-30 FRR
2009-20

CB4



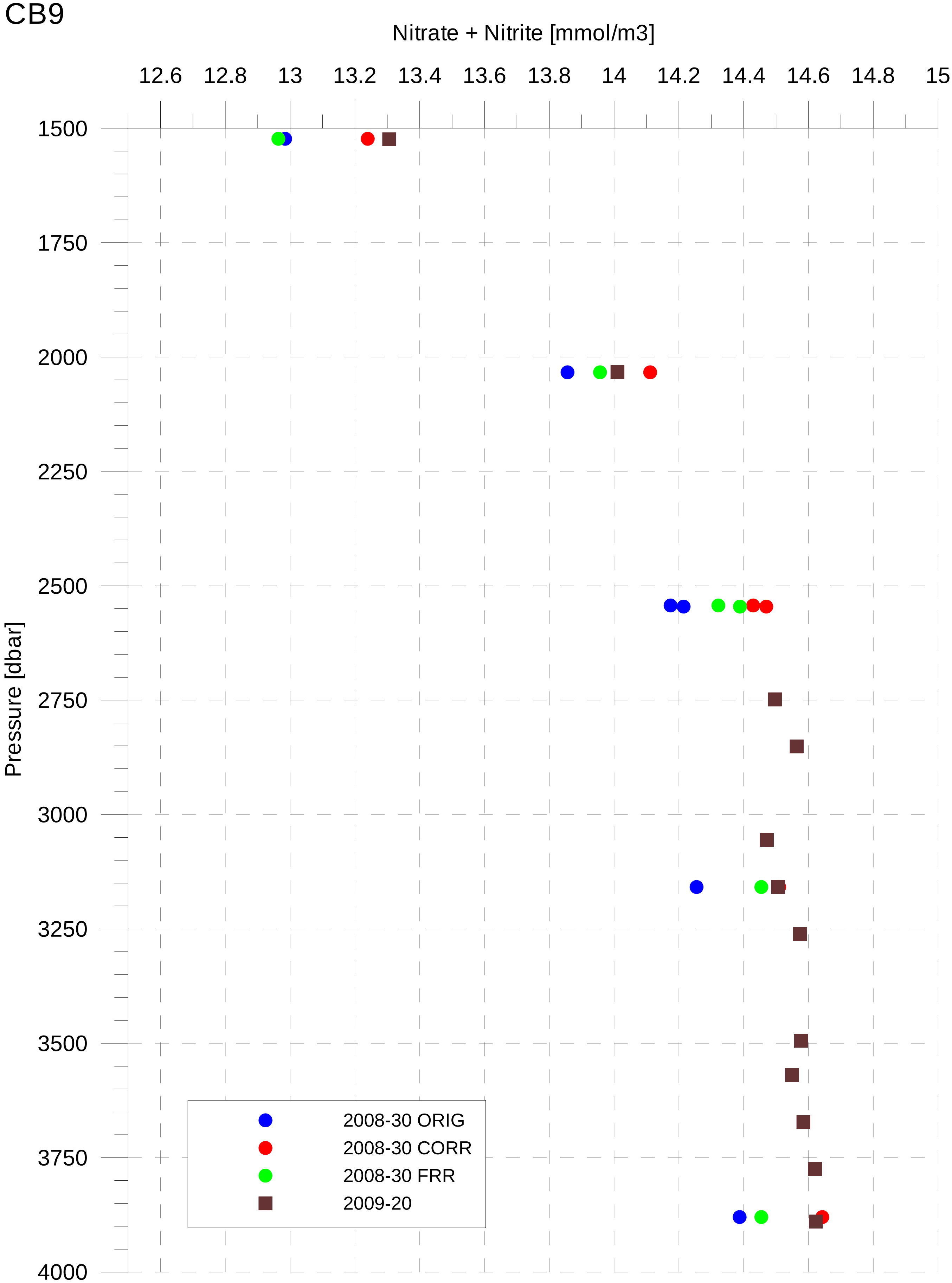
Appendix Figure A17

CB8



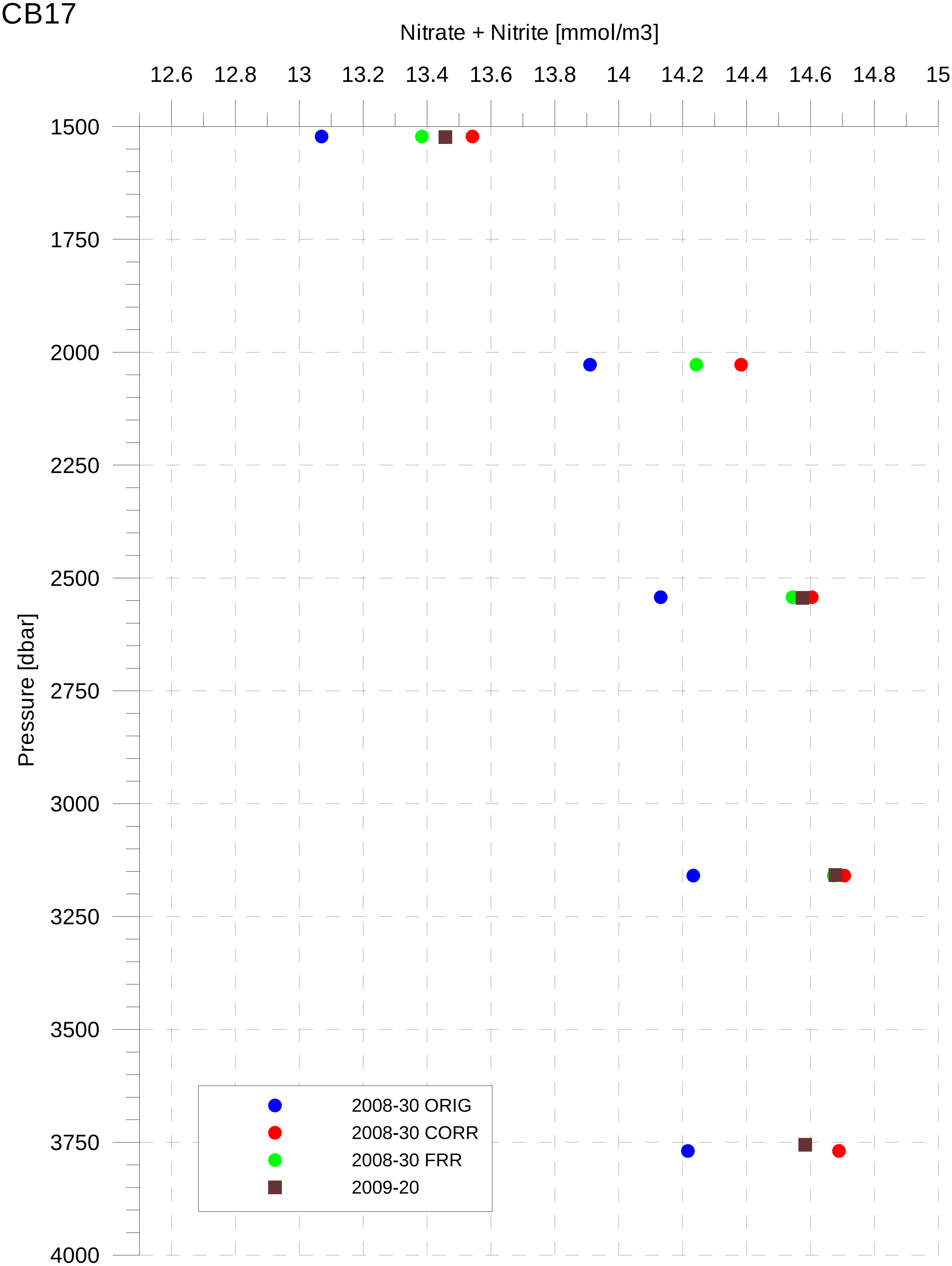
Appendix Figure A18

CB9



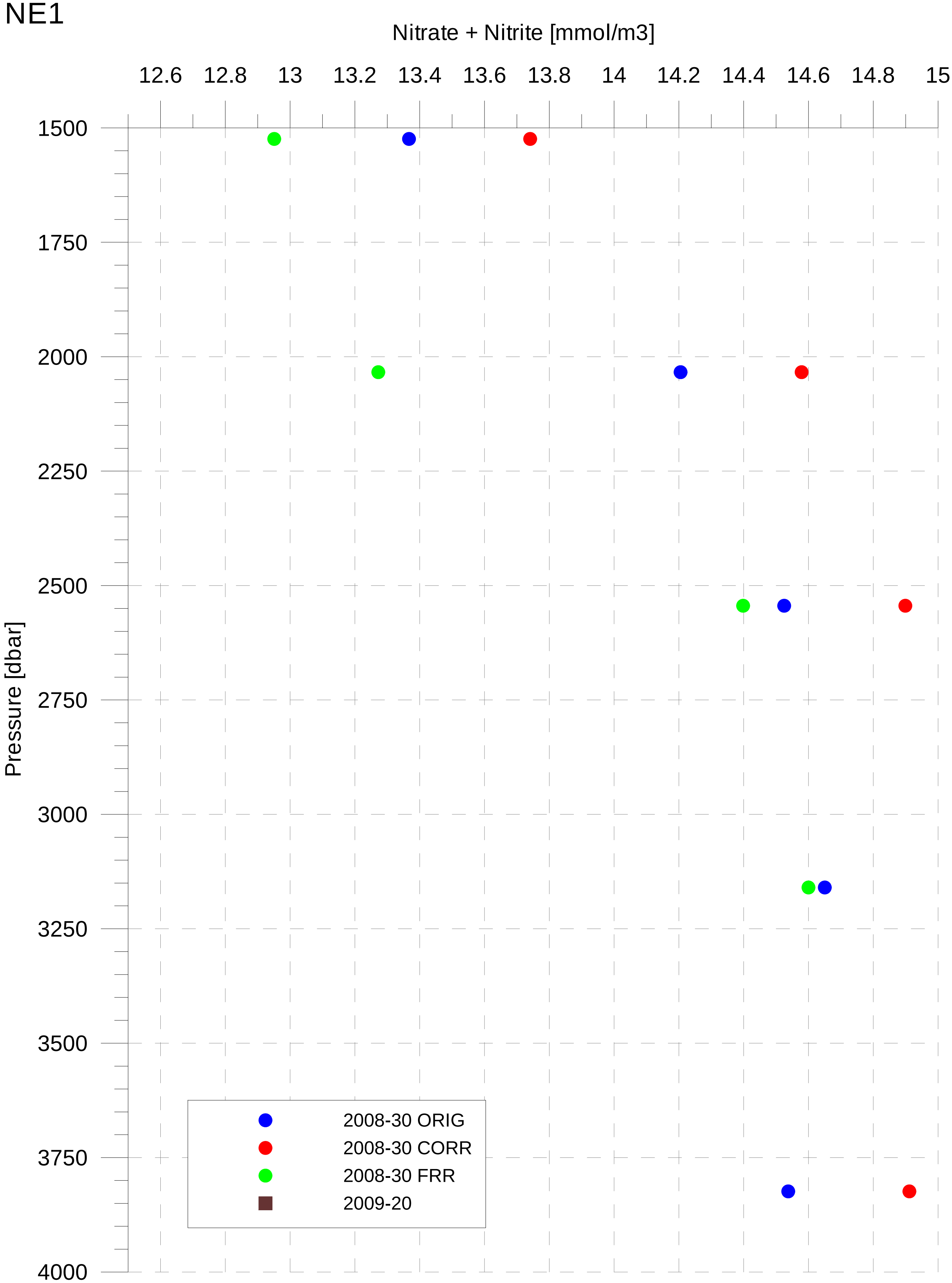
Appendix Figure A19

CB17



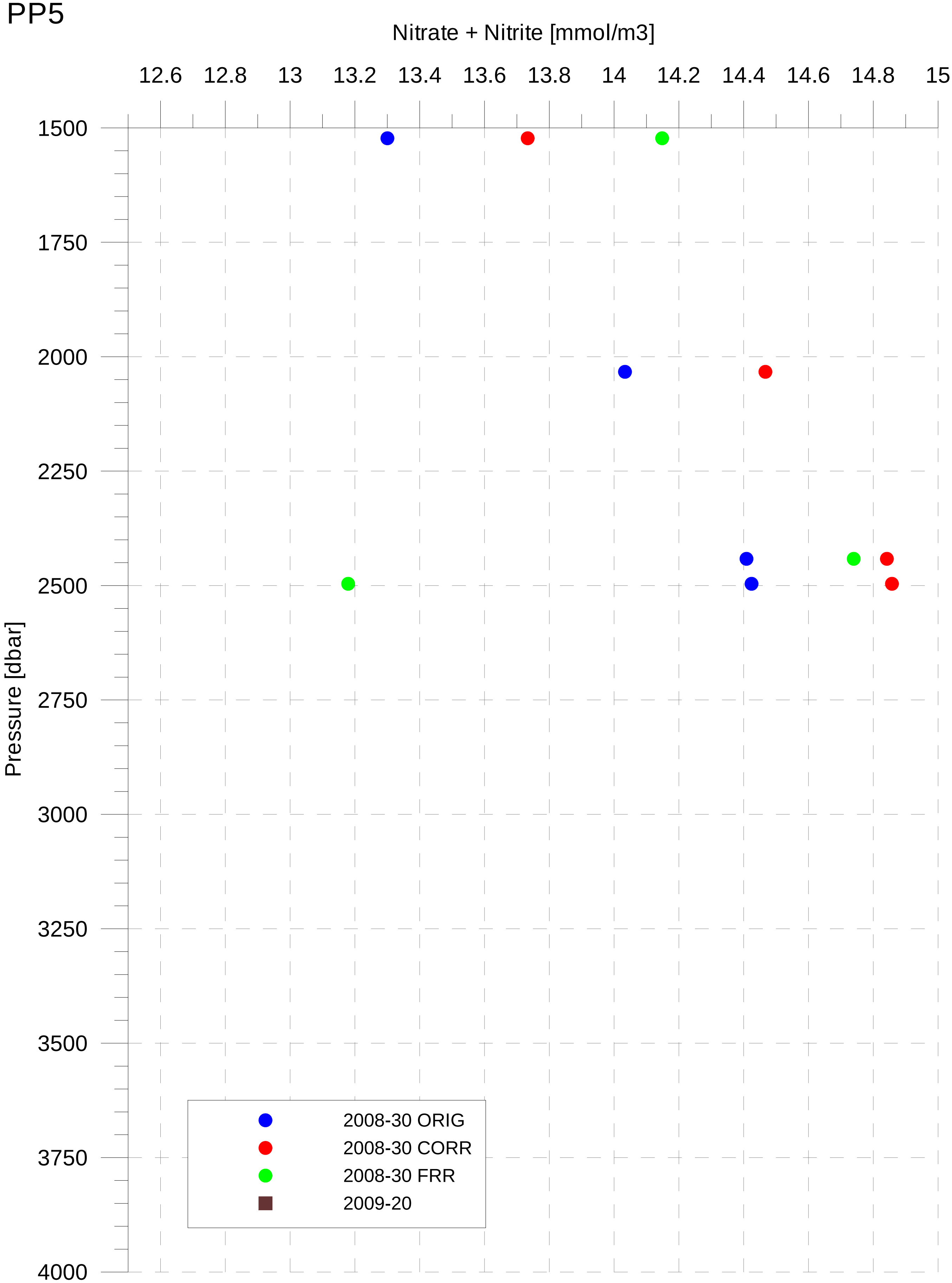
Appendix Figure A20

NE1

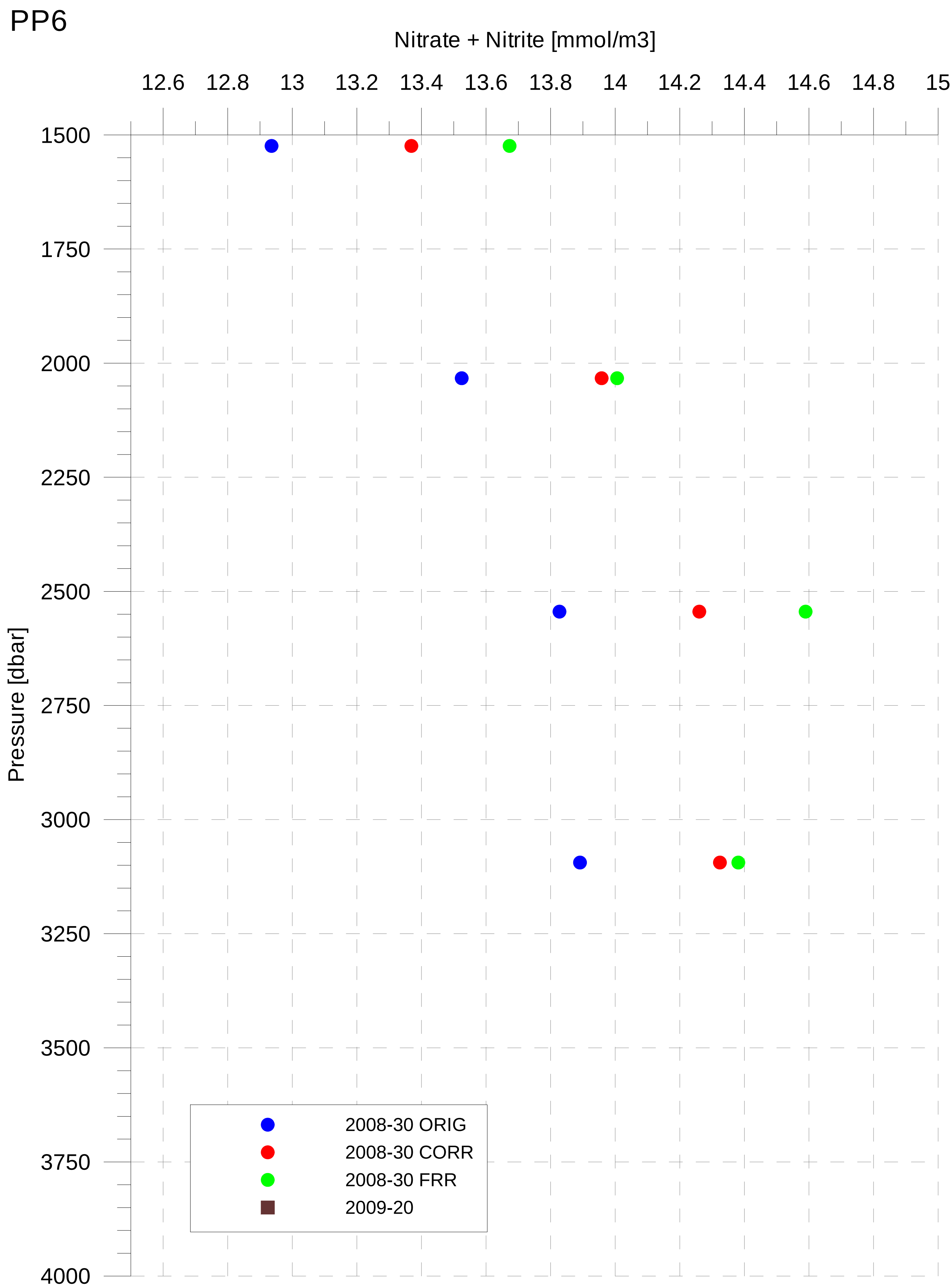


Appendix Figure A21

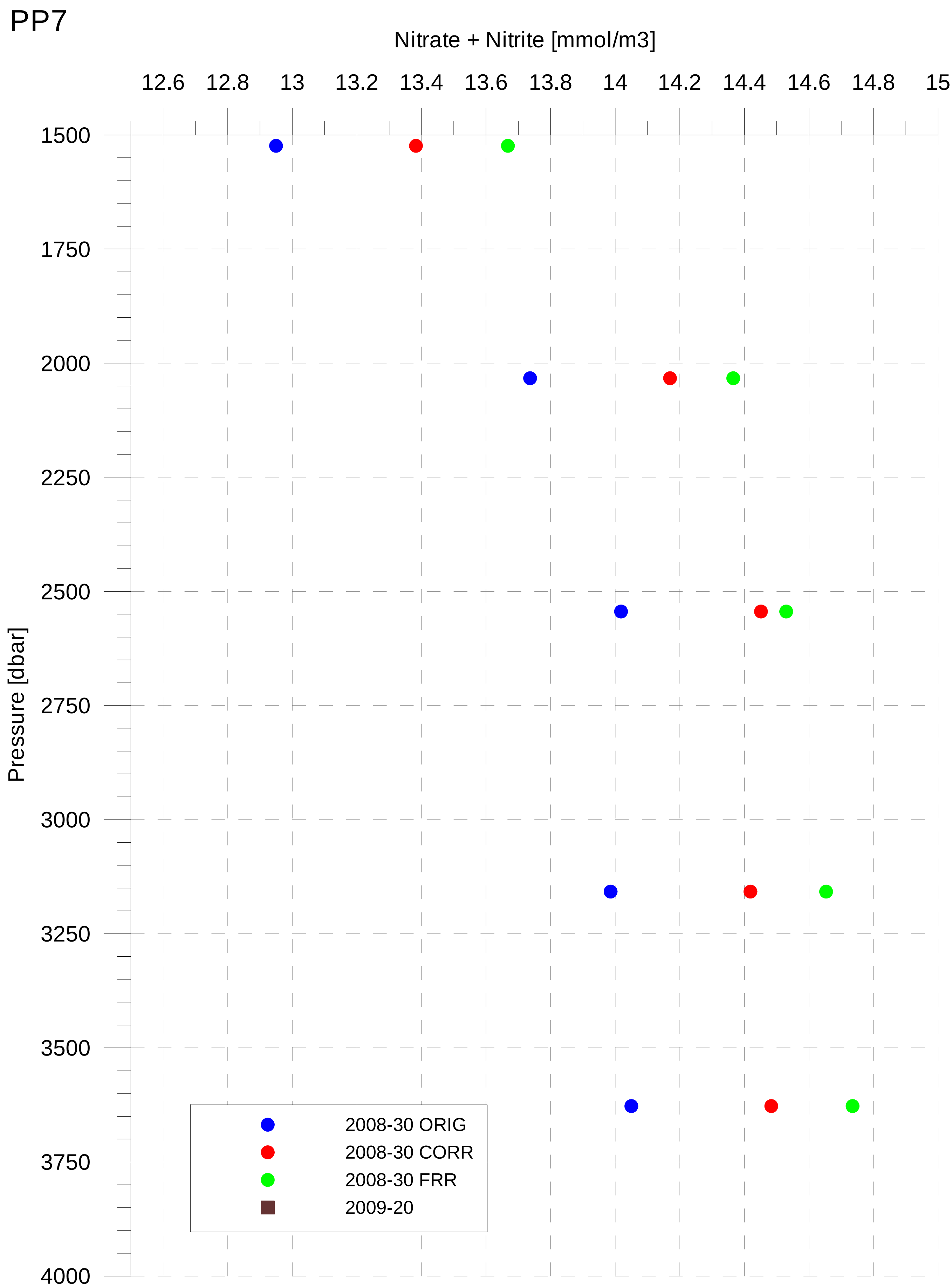
PP5



Appendix Figure A22



Appendix Figure A23



Appendix Figure A24