Supplement of

Enhancement of the North Atlantic CO$_2$ sink by Arctic Waters

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Figure S1. Monthly means of squared CCMP-2 daily winds, $U^2$ m$^2$/s$^2$. Irminger Sea region (red) and the Iceland Sea region (blue).

Figure S2. Development of surface layer density in the Iceland Sea from January 1994 to February 1996. Contour lines for density (sigma theta, kg m$^{-3}$) are shown for combined CTD data from stations Ice 4 and LNA 6, Table S1. Vertical dotted lines denote the CTD profiles. The density difference between surface and 30 m depth in late May is 0.136 in 1994 and 0.223 in 1995 and weaker stratification was generally observed in 1995 for the phytoplankton growth period.
Figure S3. Thermodynamic relations of alkalinity, total inorganic carbon and the equilibrium \( pCO_2 \) in seawater (µatm) plotted for \( S=35 \) and \( t=5^\circ C \). The red square represents Atlantic Water which reaches the Nordic Seas and has \( TCO_2/Alk=0.935 \). The slopes, \( \Delta TCO_2 /\Delta Alk \), of the \( pCO_2 \) contours in the vicinity of the square have a value of ~0.85 which describes the relative proportions of alkalinity and TCO2 additions to maintain unchanged \( pCO_2 \). Figure drawn using the Ocean Data View program (Schlitzer, 2018).

Estimated influence of alkalinity input on seawater \( pCO_2 \).

Estimate 1. Alkalinity added with river runoff.

Estimated river runoff to the Arctic Ocean is \( 4.2 \times 10^3 \) km³ yr⁻¹ or \( 0.133 \times 10^6 \) m³ s⁻¹ (Carmack et al., 2016). Taking the average alkalinity, 1048 µmol kg⁻¹, for river flow to the Arctic Ocean (Cooper et
al., 2008), then the river derived alkalinity transported by ocean currents towards the North Atlantic, would be: $0.133 \times 10^6 \text{ (m}^3 \text{ s}^{-1}) \times 3.15 \times 10^7 \text{ (s yr}^{-1}) \times 1048 \times 10^{-3} \text{ (mol m}^3 \text{)} = 4.4 \times 10^{12} \text{ mol yr}^{-1}.

Estimate 2. Effects of excess alkalinity in Polar Water.

The Polar Water volume transport by the East Greenland Current is estimated 3.9 Sv (Våge et al., 2013). Nondal et al. (2009) give two equations (Eq 6 and Eq 7) for linear salinity-alkalinity relationships for Atlantic and Polar Waters:

Atlantic Water: $\text{TA}= 49.35 \times S + 582.00$ for $S>34.5$  
Eq 6

Polar Water: $\text{TA}= 15.29 \times S + 1751.73$ for $S<34.5$  
Eq 7

For the mean salinity $S=33.0$ for the EGC Polar Water and using equations 6 and 7 in Nondal et al. (2009), the Polar Water mean alkalinity is 2256 µmol kg$^{-1}$ which is 46 µmol kg$^{-1}$ greater alkalinity than that of the North Atlantic Water calculated at the same salinity (Nondal et al., 2009).

Thus, the excess alkalinity transported southward to the North Atlantic by the EGC is:

$3.9 \times 10^6 \text{ (m}^3 \text{ s}^{-1}) \times 3.15 \times 10^7 \text{ (s yr}^{-1}) \times 46 \times 10^{-3} \text{ (mol m}^3 \text{)} = 5.7 \times 10^{12} \text{ mol yr}^{-1}$. Such excess alkalinity would lower the $p\text{CO}_2$ of Atlantic Water by 88 µatm and increase the pH by 0.10. Using 0.85 for the $\Delta T\text{CO}_2/\Delta\text{Alk}$ changes at a constant $p\text{CO}_2$ (Fig. S3), we obtain the contribution of the excess East Greenland Current alkalinity to the uptake of $\text{CO}_2$ from the atmosphere as: $4.8 \times 10^{12}$ mol CO$_2$ yr$^{-1}$, or 0.058 Pg-C yr$^{-1}$.
Table S1. Locations and depths of stations repeated in the Irminger and Iceland Seas.

| Station no | Latitude° N | Longitude° W | Station depth, m |
|------------|-------------|--------------|-----------------|
| Irm 1      | 63.835      | 31.200       | 2682            |
| Irm 2      | 63.958      | 30.393       | 2500            |
| Irm 3      | 64.072      | 29.585       | 2009            |
| Irm 4      | 64.213      | 28.775       | 1518            |
| Irm 5      | 64.333      | 27.950       | 1000            |
| Ice 1      | 67.666      | 18.333       | 405             |
| Ice 2      | 67.850      | 17.500       | 1100            |
| Ice 3      | 68.167      | 16.167       | 1350            |
| Ice 4      | 68.417      | 14.833       | 1470            |
| LNA 3      | 67.250      | 13.567       | 1540            |
| LNA 4      | 67.500      | 13.267       | 1725            |
| LNA 6      | 68.000      | 12.667       | 1875            |
| No | Cruise number | Expocode         | Dates                 |
|----|---------------|------------------|-----------------------|
| 1  | B2-1993       | 46BS19930223     | 23 02 1993            |
| 2  | A4-1993       | 46FR19930313     | 13 03 1993 -14 03 1993|
| 3  | B5-1993       | 46BS19930414     | 14 04 1993-15 04 1993 |
| 4  | A8-1993       | 46FR19930514     | 14 05 1993-15 05 1993 |
| 5  | A10-1993      | 46FR19930526     | 26 05 1993            |
| 6  | B7-1993       | 46BS19930602     | 02 06 1993-03 06 1993 |
| 7  | B8-1993       | 46BS19930623     | 23 06 1993            |
| 8  | B9-1993       | 46BS19930707     | 07 07 1993-08 07 1993 |
| 9  | A13-1993      | 46FR19930728     | 28 07 1993-29 07 1993 |
| 10 | B10-1993      | 46BS19930825     | 25 08 1993-26 08 1993 |
| 11 | B11-1993      | 46BS19930909     | 09 09 1993            |
| 12 | B13-1993      | 46BS19931005     | 05 10 1993            |
| 13 | B14-1993      | 46BS19931019     | 19 10 1993-20 10 1993 |
| 14 | B15-1993      | 46BS19931114     | 14 11 1993            |
| 15 | B1-1994       | 46BS19940106     | 06 01 1994 -07 01 1994 |
Table S3  Iceland Sea cruises and dates for discrete $pCO_2$ samples

| No | Cruise number | Expocode   | Dates                  |
|----|---------------|------------|------------------------|
| 1  | B3-1994       | 46BS19940211 | 11 02 1994-12 02 1994 |
| 2  | SO1-1994      | 46SR19940318 | 18 03 1994             |
| 3  | SO2-1994      | 46SR19940417 | 17 04 1994-18 04 1994 |
| 4  | SO3-1994      | 46SR19940512 | 12 05 1994-13 05 1994 |
| 5  | B8-1994       | 46BS19940525 | 25 05 1994-26 05 1994 |
| 6  | SO4-1994      | 46SR19940614 | 14 06 1994-15 06 1994 |
| 7  | A10-1994      | 46FR19940623 | 23 06 1994-24 06 1994 |
| 8  | A10-1994      | 26FR19940623 | 03 07 1994             |
| 9  | JH08-94       | 58JH19940811 | 11 08 1994             |
| 10 | B14-1994      | 46BS19940916 | 16 09 1994-17 09 1994 |
| 11 | B16-1994      | 46BS19941008 | 08 10 1994             |
| 12 | B17-1994      | 46BS19941110 | 10 11 1994             |
| 13 | B3-1995       | 46BS19950306 | 06 03 1995-08 03 1995 |
| 14 | B5-1995       | 46BS19950408 | 08 04 1995-09 04 1995 |
| 15 | B6-1995       | 46BS19950429 | 29 04 1995-30 04 1995 |
| 16 | B7-1995       | 46BS19950525 | 25 05 1995-26 05 1995 |
| 17 | A9-1995       | 46FR19950627 | 27 06 1995             |
| 18 | B11-1995      | 46BS19950721 | 21 07 1995-22 07 1995 |
| 19 | A11-1995      | 46FR19950815 | 15 08 1995-16 08 1995 |
| 20 | B16-1995      | 46BS19951015 | 15 10 1995-16 10 1995 |
| 21 | B17-1995      | 46BS19951110 | 10 11 1995             |
| 22 | B3-1996       | 46BS19950212 | 12 02 1996             |
Table S4  Cruises with Underway $p$CO$_2$ measurements  2006-2007

| Cruise number | Expocode       | Dates               |
|---------------|----------------|---------------------|
| 1             | B4-2006        | 46BS20060514        | 14 05 2006-31 05 2006 |
| 2             | B6-2006        | 46BS20060710        | 10 07 2006-03 08 2006 |
| 3             | A11-2006       | 46FR20061107        | 07 11 2006-01 12 2006 |
| 4             | B3-2007        | 46BS20070206        | 06 02 2007-19 02 2007 |
| 5             | B6-2007        | 46BS20070412        | 12 04 2007-26 04 2007 |
| 6             | B8-2007        | 46BS20070514        | 14 05 2007-27 05 2007 |

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