Changes in Anthropogenic Carbon Dioxide across 24.5°N of the North Atlantic since 1992

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1. INTRODUCTION

The North Atlantic Ocean plays a significant role in the global formation of deep and intermediate water masses, with cold, deep waters being more capable of supporting a greater concentration of carbon than the warmer waters at the surface. Carbon dioxide is taken up by the North Atlantic and transported to the south at depth as part of the meridional overturning circulation (Alkama et al (2003)).

Many studies have previously focused on the inventory and transport of carbon in the North Atlantic (Risón et al, 2002; Alkama et al (2002); MacDonald et al (2002); among others), and this work follows on from these in investigating the carbon transport across 24.5°N.

In March-April 2004, a fifth repeat transect of 24.5°N in the North Atlantic was carried out on RRS Discovery. This was the third cruise on which carbon measurements have been obtained, the earlier ones being in 1992 and 1998. Station locations for each transect can be seen in Figure 1 (below).

To better constrain the North Atlantic carbon inventory and transport as part of the MOC, in March-April 2004, a fifth repeat transect of 24.5°N in the North Atlantic was carried out. This was the third time that carbon measurements had been obtained, in addition to previous research cruises in 1992 and 1998.

2. DATA PROCESSING

Calculation of Anthropogenic carbon dioxide

Anthropogenic carbon dioxide (C\text{\textsc{anth}}) was calculated using the ‘\Delta C\text{*}’ method first proposed by Gruber et al (1996), with modifications suggested by Wanninkhof (1999).

After correcting the measured total dissolved inorganic carbon (TIC) for the effects of biology and calcium carbonate dissolution (\Delta C\text{\textsc{car}}), and the pre-industrial TIC concentration (C\text{\textsc{t}}), the value C\text{\textsc{anth}} can be estimated using either water ages derived from transient tracer concentrations, or through the biological-activity-corrected TIC distributions in regions uncontaminated with C\text{\textsc{anth}}.

\[
C\text{\textsc{anth}} = C\text{\textsc{t}} - (\Delta C\text{\textsc{car}} - \Delta C\text{\text{*}})
\]

C\text{\textsc{t}} values were determined using multilinear regression technique proposed by Wallace (1995) and more recently used by Friis (2005) in the Atlantic, does not suffer the capabilities of the ‘\Delta C\text{*}’ method in this region.

\[
\Delta C\text{\textsc{car}} = \Delta C\text{\textsc{bio}} - \Delta C\text{\textsc{diseq}}
\]

\[
\Delta C\text{\textsc{bio}} = \alpha_{\text{bio}} \times \left( C\text{\textsc{t}} - C\text{\text{\textsc{act}}}, \text{\textsc{bio}} \right)
\]

Residual calculation

For each station in each transect, a linear interpolation with depth was performed on to 25db depth levels. The 1992 and 1998 data were then mapped onto the 2004 station positions and basic residuals of the data sets calculated. A similar residual calculation has been performed previously by MacDonald et al (2003) for the 1998-1992 comparison. As they noted, apparent differences are not significant for individual data points. However, general patterns can clearly be observed, and basin-wide averaging also reveals further features.

Graphical smoothing/mapping

The data was first plotted in Ocean Data View (Schlitzer (2005)) before being smoothed using the VG gridding algorithm. This uses a variable resolution, rectangular grid that varies according to the data density. The gaps visible in the 1992 plot are due to the lower resolution of data. Increased smoothing was applied, but this may have obscured the finer detail in the section.

3. RESULTS / DISCUSSION

Changes in TIC field for 1992-2004

A number of features can be readily seen in Figure 2 (centre). The 1992 TIC data was calculated from measured alkalinity and pH using the thermodynamic equations for the carbonate system, with the dissociation constants of Mehrbach et al (1973).

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4. FUTURE WORK

1. Use of other methods to calculate anthropogenic CO₂

- Gruber et al. (1996).
- MacDonald et al (2003) for the 1998-1992 comparison. As they noted, apparent differences are not significant for individual data points. However, general patterns can clearly be observed, and basin-wide averaging also reveals further features.

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5. ACKNOWLEDGEMENTS / REFERENCES

- Wanninkhof, R., Nature (768): 655-657
- Matsumoto & Gruber (2005).
- Use of multiple linear regression technique proposed by Wallace (1995) and more recently used by Friis (2005) in the Atlantic, does not suffer the capabilities of the ‘\Delta C\text{*}’ method in this region.


Carbon transport estimations

Carbon fields from 1992, 1998 and 2004 are currently being combined with the velocity fields already published by Gruber et al (2005) to calculate carbon uptake and storage over changes in the Atlantic.

Increased precipitation within the subtropical gyre and reduced formation of deep and intermediate waters leads to increases in anthropogenic carbon dioxide being released by mixing effects on the global ocean carbon cycle, resulting in a reduced uptake of atmospheric CO₂ by the North Atlantic. This may provide evidence for the diminished North Atlantic Deep Water formation and overestimation in young, surface waters (Matsumoto & Gruber (2005)). Use of multiple linear regression technique proposed by Wallace (1995) and more recently used by Friis (2005) in the Atlantic, does not suffer the capabilities of the ‘\Delta C\text{*}’ method in this region.

- Use of other methods to calculate anthropogenic CO₂

- Rik Wanninkhof at NOAA/AOML, US, Kitack Lee at Pohang Univ. of Science & Technology, Korea, and Gareth Lee at the University of California, Davis.

- Rosón et al. (2003).