

## ***Interactive comment on “Multi-decadal uptake of carbon dioxide into subtropical mode water of the North Atlantic Ocean” by N. R. Bates***

**Anonymous Referee #2**

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Review of Bates 2012, Biogeosciences

In this paper, the author uses observations at BATS from 1998-2011 to assess changes in CO<sub>2</sub> uptake by subtropical mode water (STMW), with primary attribution of changes to the North Atlantic Oscillation (NAO). The contribution is appropriate for Biogeosciences, and I recommend major revisions that focus on a better assessment of uncertainty, directly addressing lateral advection time from the STMW outcrop to BATS, and providing a better spatial context for the processes involved. General comments

1. To estimate the impact that change in STMW formation has on the DIC concentration, the author (1) assume that the trend in DIC anthropogenic is equal to that implied from the long-term trend in the atmospheric pCO<sub>2</sub> (70%), (2) that all enhancement of mesopelagic remineralization due to increased primary productivity (Lomas et al.

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- 2010) occurs in STMW, giving 20% more of the trend, and then (3) the remaining 10% is due to change in STMW formation. This is a very rough estimate, and the remaining fraction is quite small. The author needs to provide uncertainty estimates for each assumption and discuss in more detail the ability to assess STMW formation based on these data in the context of this. Uncertainty should be presented in Figure 4.

2. How long does it take for mode water outcropped to reach BATS? Only the southern reaches of the formation region reaches BATS, and this will only be approached in some years, so instantaneous communication with the surface can't be assumed in all years. This needs to be accounted for in the analysis. Change in communication / advection timescale between positive and neutral/negative NAO needs to be considered.

3. The author needs to clarify the discussion of surface BATS and STMW at BATS. Is it a direct connection or is it remote? Figure 3 suggests remote, but other discussion suggests direct. At what depth is STMW at BATS? Please provide a plot of long-term mean and variability of this depth. This will help connect discussion of MLDs/NAO, surface/STWM connections. Also, please include a map with the STWM outcrop and the BATS location. Minor comments

Page 1, Abstract " It is estimated that the sink of CO<sub>2</sub> into STMW) was 0.985 +0.018 Pg C (Pg = 10<sup>15</sup> g C) between 1988 and 2011 (~70% of which is due to uptake of Cant"  
Comment: Please put this number directly in context of whole north Atlantic sink, or at least the subtropical gyre (for example, Takahashi et al. 2009)

Page 2, "Thomas et al., 2007; " Comment: Thomas et al 2008 GBC is better reference for open north atlantic than Thomas et al 2007 (north sea)

Page 3 – discussion of the region - Need a map here to identify outcrop and BATS locations. Discuss transit times for lateral advection from formation region to BATS.

Page 6, " During a few cruises, total alkalinity was not determined analytically, and it was computed from salinity with an error of ~2.8 lmos kg<sup>-1</sup> (Bates et al., 1996). "

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Comment: Please include alk-SSS equation here

Page 8: "higher than the increase in atmospheric pCO<sub>2</sub> observed over the same period (Bates et al., 2011). " Comment: Please quote the atmospheric trend of pCO<sub>2</sub> here, instead of referring to another paper

Page 8 " Thomas et al. (2009)" Comment: Thomas et al 2008 (not 2009), I believe

Page 9, Comment: "emplace" is odd word choice

Page 10, " over the last 2 decades, the STMW has been a quantitatively important additional CO<sub>2</sub> sink term in the sink- source CO<sub>2</sub> budget of the North Atlantic Ocean. " Comment: Provide quantification against other studies, so as to show it is substantial

Page 10, "The &DICanthropogenic/t1988-2011 term was estimated earlier at 1.06 mol kg<sup>-1</sup> yr<sup>-1</sup>, " Comment: Author is assuming that it's keeping up with atmosphere. Discuss evidence and uncertainty

Page 11, "The increase in DIC due to enhanced remineralization is estimated at  $\sim 0.29 \pm 0.05$  mol kg<sup>-1</sup> yr<sup>-1</sup> (i.e., &DICbiology/t1988-2011) or approximately 19% of &DICSTMW/t1988-2011. " Comment: Please explicitly state how the enhanced remineralization of DIC number derived.

Page 12, "Despite these caveats, it appears that increase in DICSTMW due to changes at the STMW outcrop (i.e., term 2, &DICoutcrop/t1988-2011) contribute the remaining 10% to &DICSTMW/t1988-2011 (i.e., &DICoutcrop/t1988-2011 = 0.16 = 1.51-[1.06+0.29])." Comment: When the outcrop part is, by difference, only 10% and the biology part is crude to get 30%, need to address uncertainty from the 70% anthropogenic to this point

Page 12, "Notably, a significant decline in DICSTMW was observed in 2011 that coincides with a strongly negative NAO (JFM) winter phase (Fig. 1f; 2b). " Comment: This implies an instantaneous transfer of the signal from the mode water formation site to the BATS site. Levine et al. (2011) discuss a 2yr lag of the NAO signal to subtropical

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gyre, and then there is the issue of lateral advection in the mode water itself. Please discuss how long this should take and how it influences results.

Page 13, "DO and nitrate decreased(increased)" Comment: "DO decreased and nitrate increased"

Page 25, "Figure 1 . . . . surface . . ." Comment: Text suggests this should be stmw. Please make sure it is stmw, and correct references to tables herein

Page 28, Figure 2: please add to dark green, light green a small label indicating surface and stmw

Page 29, Figure 3 – Please include the approximate latitudes and depths (or ranges) that are implied for this schematic.

Page 30, Figure 4 needs units on the vertical axes and labels for the DIC component on the horizontal axes. Include uncertainty estimates.

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Interactive comment on Biogeosciences Discuss., 8, 12451, 2011.