**Ocean Science
Discussions**

Interactive comment on "**Variability of heat and salinity content in the North Atlantic in the last decade**" *by* V. O. Ivchenko et al.

Anonymous Referee #2

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Review of "Variability of heat and salt content in the North Atlantic in the last decade"
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This paper examines the changes in heat and salt content for the North Atlantic 1999-2008 based on only profiling float data. This is of some interest as the Argo program has become the main ocean observing system for subsurface temperature and salinity data and the XBT bias problem has raised doubts about another major part of the observing system. I think significant work needs to be done on the paper, mainly in the addition of background details, method details, and analysis of the data. Most critical is a deeper examination of the profiling float data used and how the data distribution and quality affect the estimated trend. Also, there should be some discussion as to whether a linear trend is really the best way to understand the 10 year time series and

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more effort to put the present results in context of previous studies. Details are below. [Citations mentioned which are not in the paper are given after each point. This is just for convenience, as the authors are probably aware of the papers.]

- Much more information about data distributions needs to be added. A recent paper (von Schuckmann et al. 2009) shows an increase in heat content globally 2003-2008. However, this result may be in part due to the lack of data in the southern hemisphere for the first few years of the study artificially lowering the heat content for those years (or increasing it when data was available in later years). This study used data from 1999-2008. However, there were very few floats in 1999. The pressure offset problem in the FSI floats created a big data gap 2004-2008. The heat content appears to increase mostly between 2003-2004 and to be level before and after that. The authors need to show data distributions for each year and to be able to show the heat content and salt content patterns are not in some way due to changes in data distribution.

von Schuckmann, K., F. Gaillard, P.-Y. Le Traon, 2009, "Global hydrographic variability patterns during 2003-2008", Journal of Geophysical Research, 114, doi:10.1029/2008JC005237

- More information about data handling/data quality needs to be added. There is little mention, and no direct mention, of real-time vs. delayed-mode quality control of the Argo floats. This is especially critical for the salinity data, as a huge effort is expended to correct for salinity drift in the delayed-mode data and this information is not always in the real-time data. Were real-time or delayed-mode temperature and salinity data used in this study, or were both used, depending on availability? If any but delayed-mode data were used, there should be some justification. Also, in the early float years, there were many problems with the conductivity sensor, many related to biofouling. These problems were lessened by turning off the sensors in the top 5 meters and using biocide. But the pre-Argo floats which make up the bulk of the floats in the earlier years of this study do not have these fixes. This should be discussed in the context of the results. Were a large number of salinity (and/or temperature) profiles thrown out in

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the standard deviation check for the early years of this study? What of the quality of the remaining data for those years?

- Does a linear trend give the best indication of the pattern of the time series for this study? Figure 10 shows that it may for salinity, with a steady increase and a big increase then decrease in 2004-2006. Figure 5 shows that the linear trend may not be the best way to represent the heat content time series. Heat content is flat 1999-2003, rises abruptly, and is flag again 2005-2008. There should be some discussion of patterns outside the context of the linear trend. At the very least, some indication of what percent of the change in the time series is attributable to the linear trend.

- The authors cite Resnyansky as confirming the general warming of the ocean 2005-end of 2007. However there are a number of published works that show that there is no trend over this period, and through the present. Willis et al (2009), Levitus et al. (2009) are among these works. If the authors want to discuss recent trends in heat content, they need to be more thorough.

Willis, J. K., J. M. Lyman, J. M., G. C. Johnson, and J. Gilson, 2008, "In situ data biases and recent ocean heat content variability". Journal of Atmospheric and Oceanic Technology, doi:10.1175/2008JTECHO608.1.

Levitus, S., J.I. Antonov, T.P. Boyer, R.A. Locarnini, H.E. Garcia, and A.V. Mishonov, 2009, "Global Ocean Heat Content 1955-2008 in light of recently revealed instrumentation problems.", Geophys. Res. Lett. , 36, L07608, doi:10.1029/2008GL037155.

- The authors should offer a little analysis and comparison of their results. The authors cite Curry and Mauritzen and their work quantifying an increase in fresh water content through the mid-1990s. How does the increase in salt content since 1999 compare with the large freshwater increase that ended in the mid-1990s? How does calculating change in salt content compare with calculating change in freshwater content? Boyer et al. 2007 have estimates of freshwater change through 2006. How do the changes found in the present work compare with the changes found in this paper? There are

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other papers dealing with heat content and salt (fresh water) changes in the North Atlantic as well, such as Polyakov et al.. 2005. The present paper really needs to put its results into some sort of context to these earlier papers.

Boyer, T., S. Levitus, J. Antonov, R. Locarnini, A. Mishonov, H. Garcia, and S. A. Josey, 2007, "Changes in freshwater content in the North Atlantic Ocean 1955 - 2006", Geophys. Res. Lett., 34, L16603, doi:10.1029/2007GL030126

Polyakov, I. V., U. S. Bhatt, H. L. Simmons, D. Walsh, J. E. Walsh, and X. Zhang, 2005, "Multidecadal Variability of North Atlantic Temperature and Salinity during the Twentieth Century", Journal of Climate, DOI: 10.1175/JCLI3548.1

- Whether the authors have detailed the analysis procedure in other papers or not, some more details need to be in this paper. The most important is the fill-values used (or not used). Lyman and Johnson (2008), AchutaRao et al, 2007, show how different default or initial values in data sparse areas can have a significant effect on heat content calculations. The present paper needs to discuss this, both in the context of the importance of data converage on the heat and salt content estimates and on the differences/similarities when subsetting the data set for stability calculations.

Lyman, J. M. and G. C. Johnson, 2008, "Estimating Annual Global Upper-Ocean Heat Content Anomalies despite Irregular In Situ Ocean Sampling", Journal of Climate, DOI: 10.1175/2008JCLI2259.1

AchutaRao, K.M., M. Ishii, B.D. Santer, P.J. Gleckler, K.E. Taylor, T.P. Barnett, D.W. Pierce, R.J. Stouffer, and T.M.L. Wigley, 2007, "Simulated and observed variability in ocean temperature and heat content", Proceedings of the National Academy of Sciences, 104, doi:10.1073/pnas.0611373104.

- A little more information on the stability check (calculating heat and salt with subsets of the initial data set) is needed. What does "near random" selection mean? What does the data coverage look like for the 1/2 and 1/4 dataset cases? Does near-random

selection leave some areas data sparse or is the selection process smart enough to leave all ocean areas as fully covered as possible? Also, why is the log of the results graphed instead of the full values? Would graphing the full values essentially show no apparent difference so a different graphing was used to reveal differences? If so, state this.

- If the authors claim that Argo data allows resolution of the problem of synchronisation, they need to define synchronisation precisely. The stated goal of the Argo project is to measure temperature and salinity in the upper 2000 db of the water column a minimum of every 10 days over every 3 X 3 lat/lon box around the ice-free ocean outside marginal seas. Is this how you would define synchronisation? And if so, has Argo met this goal in the North Atlantic. If your definition is tighter or looser than this, state it. And what is the importance of the lack of data along the shelf region, Gulf of Mexico, other areas?

- The authors state that the negative heat content relative to the Levitus climatology is probably caused by the XBT bias found by Gouretski and Koltermann. Chang et al (2009) constructed temperature climatologies for the years 2003-2007 and found that they were warmer than the corresponding Levitus climatologies, despite the XBT bias present in the Levitus climatologies. Please explore this futher.

Change, Y-S, A. J. Rosati, S. Zhang, and M. J. Harrison, 2009, "Objective analysis of monthly temperature and salinity for the world oceanin the 21st century: Comparison with World Ocean Atlas and applications for assimilation validation", Journal of Geophysical Research, 114, doi:10.1029/2008JC004970

- How is level of significance calculated?

- In general the paper was free of grammatical errors and well written. The only misspelling I found was on page 1976 'Updated list of "uncorrecatble"' should be 'Updated list of "uncorrectable"'.

Interactive comment on Ocean Sci. Discuss., 6, 1971, 2009.