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**Monitoring Atlantic overturning circulation variability with GRACE-like ocean bottom pressure observations - a sensitivity study**

# Statement of Revision II

"The theory presented in the article is neither novel nor very complicated (which could justify discussing theoretical and real results in seperate papers), the framework to derive the AMOC variations from GRACE-like data has been set up and the GRACE data performing best (JPL CRI mascons) are available at the author?s institute. Therefore, including actual results should be feasible (although not trivial, given that the noise in the GRACE data was neglected in the sensitivity study). This would make for a much more exciting paper, with a much higher contribution to the scientific progress. However, as said before, the methods and results look sound, so I will leave it up to the editor to decide if this manuscript should be accepted for publication in its present form."

The Referee states that the article might lack of scientific results since the article does not show any results from real data. We share the opinion of Referee #2, who states that the article would result in an extremely long article if results from real data were to be included. Indeed, the basic theory behind deriving transport from ocean bottom pressure is not very complicated. However, using ocean bottom pressure from satellite gravimetry to derive ocean transports is not trivial, since the signals are on the edge of the resolution and sensitivity of satellite gravimetry. We believe this simulation study is essential and justified to examine sensitivity of the available ocean bottom pressure observations derived from satellite gravimetry. It is important to know about strength and weaknesses of the method before simply applying it to real data. Furthermore, there are not many appropriate validation data sets for results from real data. In-situ data are sparse, and they are point measurements, while satellite observations cover large areas. Furthermore, in-situ data also have errors and suffer from drift. Assessing transport from other remote sensing methods, like altimetry, have errors that propagate into a transport estimate.
Thus, we believe the present study serves as a rigorous assessment of what to expect from the data with regards to recovering the MOC signal. It will serve as a guide for the user to better understand the advantages and limitations as well as provide an error estimate of the impacts of the resolution.
"For what it's worth, in the meantime, a paper has been published in GRL by the same authors, which presents actual results from real GRACE data and compares them to RAPID/MOCHA data as validation. The Introduction and Methods & Data section of the GRL paper are more or less a summary of the same sections in this paper. Given the typical length of a GRL paper, I don't think including the results would result in an 'extremely long article'. Don't get me wrong, I do think the material presented in this paper deserves to published in some form, I just find it regretful that the authors have decided to split the theory and actual results in two separate papers (on the other hand, I realize we're all victim of the publish-or-perish culture, one way or another)."

This comment addresses an important issue - but at this point there is no recourse, and we also reiterate our earlier stance that the more theoretical aspects discussed in detail here warrant a stand-alone publication. This sentiment was also supported by the initial second reviewer.

"The authors find that GRACE-like observations can capture AMOC variations with an interannual RMS error of about 1 Sv. However, it's unclear how this compares to the interannual variability of the AMOC itself. Is this 1 Sv error small enough to still detect a useful signal? This deserves to be discussed in more detail."

We added a new Fig. 9 in order to clarify this point and discussed in in text. The error of about 1 Sv is about 50% of the signal magnitude of AMOC anomalies, which is roughly about 2 Sv. Fig. 9 shows that GRACE-like OBP observations are nevertheless capable to capture the signal with a correlation of 0.63 with the model reference (for this example-latitude).

"Include this signal RMS (i.e. of the model reference, red line) in the caption."

We included the model baseline RMS in the caption, as well as clarified the error RMS values.

"The simulations and results are based on the assumption that the GRACE data are free of error (BTW, this should be mentioned clearly in the abstract). This is justified, but a short discussion should be included on how these errors will affect the results when working with real data. Chambers and Bonin (OS, 2012) found an error of 1.5-2.5 cm water equivalent in the North-Atlanic. How would this translate into AMOC transport error?"

[...] Chambers and Bonin (OS, 2012) found a mean error of 2 cm in the spherical harmonic GRACE solutions in the North Atlantic. A 2 cm error in ocean bottom pressure would result in an error of about 0.002 Sv/m in the derived transport. Assuming the northward transport layer spans roughly 1000 m, this leads to an error of about 2 Sv from spherical harmonics. However, we note that mascon data errors are estimated to be about 30% smaller than this in the current study region (see Watkins et al. 2015).

"Include this last paragraph in your article. It's important the reader gets a feel of what performance to expect from real GRACE data."

We included a slightly modified version of this paragraph in the summary and outlook chapter.

"Finally, an important scientific question is whether the AMOC is declining in strength or not. The summary and outlook sections should briefly mention this and discuss how feasible this is with GRACE data (will GIA be a problem? How many years of observations would be required to detect a significant trend, given the 1 Sv error in this study?)."

Indeed, AMOC trends are of great interest. Trends in the ocean bottom pressure can be recovered by GRACE, however, the uncertainty in GRACE trend corrections for GIA (from models) and leakage correction can significantly corrupt a transport-related OBP trend. In addition, the ECCO2 model is not free from model drift, which must be corrected for. An unrealistic drift could contaminate the statistics here. Therefore, we decided to remove the trend and only focus on interannual signals. A detailed trend correction study for GRACE is beyond the scope of this paper, however, we intent to pursue a detailed evaluation in future studies (same answer as to Referee #2's question).

"I'm not expecting you to give a detailed trend correction, just to briefly mention the main limitations of GRACE in detecting AMOC trends (GIA, leakage,...). People working with GRACE are familiar with these limitations, but a typical physical oceanographer, for example, may not. Informing the general audience about these limitations is especially important since you mention the drift problem of in-situ OBPs a couple of times as an argument for gravimetric monitoring of the AMOC."

We also added a sentence explaining the trend correction difficulties in the summary and outlook chapter.

"**-minor comments:**
line 168: change 'are not sufficient' to 'may not be sufficient', or otherwise provide actual evidence that these corrections are not sufficient."

We changed this.

"line 312 (and elsewhere): the significance level isn't defined."

The significance level of 95% is given now, in the figure caption and in the text.