Response to Interactive comments by Anonymous Referee 1 on "High frequency variability of the Atlantic meridional overturning circulation" by Balan Sarojini et al.

We thank the reviewer for supporting the publication of the paper.

Line 67: authors might like to cite the COREs by Griffies et al. (2009).

Griffies et al. (2009) will be cited at Page 222, Line 1.

Chapter 2, Line 90 I would suggest to add 'in the ocean' after 'substantial differences'

This will be changed as suggested, at P.222, L.24.

In the chapter 3 the authors show that the high frequency amplitude of variability does not depend on resolution and is induced by the winds. In turn, models with UVic atmosphere do not show this variability. Is the wind field prescribed as stationary in UVic? Would it change much if the variable wind is prescribed?

The UVic atmosphere in both GENIE and FRUGAL uses prescribed annual wind-stress climatology. We will state that at P.225, L.13 and P.238, Table 1 caption. However, in a further FRUGAL experiment done with a representation of the SST-wind-stress feedback, no significant change was found in AMOC variability. Also, in a GENIE experiment with imposed stochastic variability in wind and precipitation fields, there was still little AMOC variability. We will mention these points at P.225, L.15.

Chapter 4, starting from line 237 authors say that geostrophic transport variability is smaller than the Ekman constitute and is the case for high frequencies and seasonal cycle. This is attributed to the underestimated adiabatic upwelling/downwelling from alongshore windstress. I would think that the geostrophical seasonal cycle is driven mainly by the surface fluxes. Thus the underestimated variability might also indicate the problems in the vertical mixing scheme (or imperfect fluxes). The deeper look into the eastern/western density profile variability would probably tell more about what happens. Would Figure 2 become better if plotted for HiGEM?

We agree with the reviewer that the geostrophic seasonal cycle is mainly driven by surface fluxes, so unrealism in either the surface fluxes or the vertical mixing caused by the surface fluxes could be the cause of underestimated variability. Variability in the real world is found to be due to the effect of the seasonal momentum flux on the eastern boundary density (Chidichimo et al., 2010 ; Kanzow et al., 2010). This might not be represented in the coarse-resolution RAPID models. In HiGEM, the geostrophic seasonal cycle has more variability than that in HadCM3, and HiGEM geostrophic transport will be shown in a new figure and discussed in the text.

Line 242: should not it be 'variability of pressure anomaly' instead of 'pressure anomalies'. The variability of transport is discussed and not the mean.

The reviewer is right. The text will be changed.

Line 253: Isn't the physical mechanism the fact that the pressure at large depths varies less than the dynamic height and the latter is compensated by the hydrostatic pressure?

We think that the reviewer's suggested physical mechanism is not entirely satisfactory, as this does not explain why the compensation occurs. Other than that, we agree with the reviewer that this is indeed what is happening. This will be rephrased accordingly.

Chapter 5: Might Ekman transport anticorrelation for widely spaced latitudes be associated with moving front between subpolar and subptropical gyres?

Yes, we agree with that, and will expand the remark.

line 298: remove 'which'

This will be done.

Chapter 5: The time lag between 26 and $M_{\max}$ which is at higher latitudes was mentioned few times in the chapter. At the end it is said that the higher latitude precedes the lower one with the time lag of 4 years. I suggest to say some words about the mechanism behind this lag.

Changes in deep water formation occurring at the high latitudes initiate Kelvin waves which propagates southward along the western boundary. These coastally trapped Kelvin waves are manifest as transport anomalies at each latitude as they propagate from the north to the equator and from there eastward to the eastern boundary and further poleward (Johnson and Marshall, 2002). A recent study by Zhang (2010), using a coupled AOGCM which represents the interior pathways of North Atlantic Deep Water in the mid-latitudes as observed by Bower et al. (2009), found that AMOC variations propagate in an advective manner in the mid-latitudes and at the speed of Kelvin waves in the sub-tropics along the western boundary. This will be discussed in Chapter 5.

Line 309: It is claimed that the high latitude AMOC index has its greatest importance for climate variability and the reader is referred to chapter 6. It is however not explained in chapter 6.

We meant to say that the high-latitude AMOC index is more important for climate variability because it is the one that is supposed to most directly reflect the rate of deep water formation, which is obscured by wind-driven variability in the AMOC index at $26°N$. This will be mentioned in Chapter 6.

Concerning summary: The absence of the systematic relation between the model resolution and the magnitude of transport variability is partially because the whole section was taken into account and was not treated as the constitutes of several subsections as it is often done. Thus no eddy passes over the endpoint of the section. The results point out that the across-section eddy translation is small.

This is a reasonable argument, but we would point out that we are evaluating the transport above a fixed depth. If the eddies are on isopycnals which may have a zonal slant the compensation may not be complete. In addition, note that the issue is not that straightforward, since Wunsch (2008) contended that eddies could possibly dominate the variability of the measured transport, and thereby prevent the detection of a possible trend in too short records. Since recent studies such as Kanzow et al. (2009), it is increasingly appreciated that eddies would be swept away as coastally-trapped waves upon reaching the western boundaries, leaving only a weak signal in the zonally-integrated volume transport. Finally, note that all models used are of coarse resolution, except one which is eddy-permitting; the relative insensitivity to model resolution could therefore be due to the fact that none of the models are able to generate enough eddy variability for this to affect the simulated transport variability. It would certainly be interesting to see whether a qualitatively different behaviour would be observable in an eddy-resolving model, as this would be the only way to settle the issue. This will be discussed in the revised version.

Line 372: in 26N ^{o}N is forgotten.

This will be corrected.

At many places where citations are done there are no points after et al., like in line 59. Something is wrong with bibtex, probably.

We will check the formatting.

REFERENCES

Bower, A. S., M. S. Lozier, S. F. Gary, and C. W. Boening : Interior Pathways of the North Atlantic meridional overturning circulation. Nature, 459, 14, doi:10.1038/nature07979, 2009.

Chidichimo, M. P., T. Kanzow, S. A. Cunningham, and J. Marotzke : The contribution of eastern-boundary density variations to the Atlantic meridional overturning circulation at 26.58N. Ocean Sci., 6, 475-490, 2010.

Griffies, S. M., A. Biastoch, C. Bning, F. Bryan, G. Danabasoglu, E. P. Chassignet, M. H. England, R. Gerdes, H. Haak, R. W. Hallberg, W. Hazeleger, J. Jungclaus, W. G. Large, G. Madec, A. Pirani, B. L. Samuels, M. Scheinert, A. Sen Gupta, C. A. Severijns, H. L. Simmons, A. M. Treguier, M. Winton, S. Yeager and J. Yin : Coordinated Ocean-ice Reference Experiments (COREs). Ocean Modelling, 26, 1-46, 2009.

Johnson, H. L., D. P. Marshall : A Theory for the Surface Atlantic Response to Thermohaline Variability. J. Phys. Oceanogr., 32, 1121-1132, 2002.

Kanzow,T., H. Johnson, D. Marshall, S. A. Cunningham, J. J.-M. Hirschi, A. Mujahid, H. L. Bryden, and W. E. Johns : Basinwide integrated volume transports in an eddy-filled ocean. J. Phys. Oceanogr., 39, 3091-3110, 2009.

Kanzow, T., S. A. Cunningham, W. E. Johns, J. J-M. Hirschi, J. Marotzke, M. O. Baringer, C. S. Meinen, M. P. Chidichimo, C. Atkinson, L. M. Beal, H. L. Bryden,and J. Collins : Seasonal Variability of the Atlantic Meridional Overturning Circulation at 26.5N. J. Climate, 23, 5678-5698. doi: 10.1175/2010JCLI3389.1, 2010.

Wunsch,C.: Mass transport variability in an eddy-filled ocean. Nature Geoscience,1,165-168, 2008.

Zhang, R.: Latitudinal dependence of Atlantic meridional overturning circulation (AMOC) variations, Geophys. Res. Lett., 37, L16703, doi:10.1029/2010GL044474, 2010.