Answer for Referee 2

Thank you very much for the careful review you have done of our paper. We really appreciate all your comments and we took them into account in our revision.

GENERAL COMMENTS

At a first glance, the method with the division of the transport into a net, iso- and diapycnal component seems to be reasonable. If looking at the details, however, I am not so convinced whether this approach is really optimal for the inetrpretation of Cant transports. My objections are the following: For calculating the MOC, the use of isopycnal coordintes is probably the best one can do. Things become different when looking at the so called isopycnal component: In the paper by Böning and Herrmann (1994), this component was defined in z-coordinates and interpreted as a 'gyre' component. This means for the case of the OVIDE section, that warm and Cant rich surface water is transported northward with the North Atlantic Current (NAC), whereas in the Irminger Sea cold and Cant rich surface water is transported southwards. The surface waters of the Irminger Sea have higher densities than the surface waters within NAC. Thus, when using isopycnal coordinates, the northward Cant transport related to the NAC occurs completely in the diapycnal (overturning) component (Fig. 5C), whereas the southward transport related with the surface waters of the Irminger Sea occurs in the isopycnal component (Fig. 4C). This means that horizontal and isopycnal transports are not the same, which the authors do not seem to be aware of (e.g. p.16105, l. 21, 'the horizontal or isopycnal transport ...').

We do totally agree with the referee that horizontal and isopycnal transports are not the same. This issue is well explained by the co-authors of this paper in Lherminier et al (2010) and Mercier et al (2013). We apologize for this unfortunate formulation in line 16105 that is now corrected. We checked the manuscript for an adequately use of "horizontal" and "isopycnal" and we added a new sentence in section 3 where T_{cant}^{isop} is defined for the first time. The sentence is:

"This term is usually called horizontal circulation when the decomposition is done in pressure coordinates (e.g. Bonning and Herrmann, 1992), however, in our case, it is not the horizontal circulation since isopycnals present important slopes all along the section (see figure 2)."

Another result of the decomposition of the Cant flux is the large northward diapycnal flux in the overflow waters, contrasted by a large southward isopycnal component. The high value if TCant_diap for the deep waters are the result of a negative value of <v> (the southward flow of overflow waters mainly over the nothwestern part of the OVIDE section) combined with a negative valu of <Cant> in the deep waters. The authors state that the overflow waters at 60_N are poor in Cant because of entrainment/dilution (p. 16113, l. 25). However, for me it seems that the negatie value of <Cant> in the deeep waters is mainly caused by the old AABW in the eastern part of the section, whereas the overflow waters in the northwestern part have intermediate Cant values (see Fig.2). This means, that the (western) core of negative velocities and the (eastern) core of negative Cant anomalies are not colocated, and the large positive value of <Cant><v> for the deep waters is just an artefact. This artefact is compensated by the large negative value of Tcant_isop for the deep waters, so the total transport is correct. In the light of this, one cannot simply interprete the term Tcant_diap as 'transport of Cant linked to the diapycnal circulation that accounts for

the light to dense water mass conversion' (p. 16110, l. 4), as the overflow waters, which form the lower limb of the diapycnal circulation, clearly transport Cant southward (i.e. TCant_diap for the overflow waters should be negative), but here they have a positive contribution to TCant_diap due to the above mentioned reasons. (For the heat transport, this effect is much smaller, as the temperature difference between overflow waters and old AABW is relatively small in contrast to their large difference in Cant concentration). In the paper by Mercier et al. (2013), a similar decomposition is done for the heat flux, but there the potential temperature is only devided into two compnents, <theta> and theta', there is no theta0 substracted. If Cant would also only be decomposed into <Cant> and Cant' without substracting Cant0, <Cant> would be positive everywhere, and TCant_diap for the overflow waters would become negative. I would strongly recommend to redo the calculation of TCant_diap and TCant_isop without the substraction of Cant0.

We really appreciate the proposal of the referee of splitting the Cant concentration in only two terms instead of three. We adopt it for several reasons: 1. It is true that the overflows transport Cant southward as part of the diapycnal component of the circulation as the referee said and it was not clearly showed in the results obtained using the old formulation; 2. We will show in the following that it does not affect the integrated quantities (T_{cant}^{net}, T_{cant}^{diap} and T_{cant}^{isop}), so the final results and conclusions of our work do not change at all; 3. With the new formulation the method is closer to that used for the potential temperature decomposition in Mercier et al (2013); and 4. It leads to an easier understanding of the message we want to transfer to the biogeochemical community.

Explicitly, in the revised manuscript, Cant concentration is now split in two components: $Cant = \ \ Cant \ \ \ \sigma \ \ + Cant'(x,\sigma)$, so, the new equation of Tcant is:

$$T_{cant} = \rho V_0 \overline{\langle Cant\rangle(\sigma\ )} + \rho\overline{\langle v\rangle(\sigma)\ \langle Cant\rangle(\sigma)} + \rho\overline{v'(x,\sigma)\ Cant'(x,\sigma)}$$

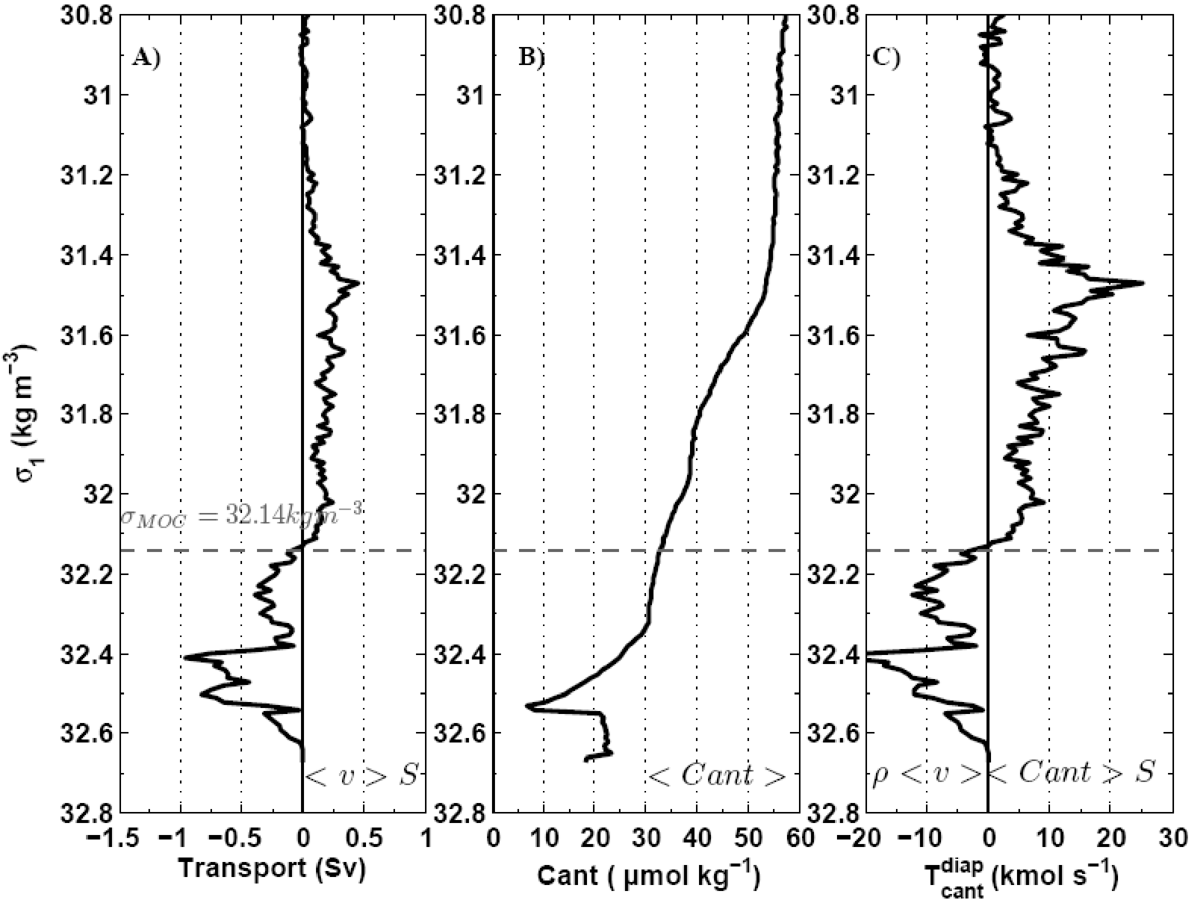
Because the overbar denotes an area integration, $\rho V_0\overline{\langle Cant\rangle(\sigma\ )}$ is equal to $\rho V_0 Cant_0$ (in the first formulation).

Regarding the second term on the right hand side of the equation, it is the same as before once integrated (T_{cant}^{diap}), but $Cant\ \ (\sigma)$ is now offset by the section averaged value of Cant (see new figure 5b). Consequently, a change in the vertical profile of transport of Cant is obtained (see new figure 5c). We observe now a negative transport of Cant in the density levels corresponding to the overflow waters that, as the referee explained, is due to the southward transport of the overflow waters with intermediate Cant concentrations. Now, the Meridional Overturning circulation is easily identified in the profile of transport of Cant (new figure 5c). Thank you!

The third term of the equation is exactly the same, since Cant' is the same in both decompositions.

The change of the formulation of T_{cant} had no impact on the discussion section since T_{cant}^{net}, T_{cant}^{diap} and T_{cant}^{isop} do not change compared to the old formulation. Nevertheless, the change of the formulation implies some modifications in section 3 of the manuscript and the last paragraph of section 4.2 has been replaced by the following one:

" The transport of Cant across isopycnals, that is T_{cant}^{diap}*, is decomposed in terms of mean profiles of anomalies of volume transport (Fig. 5a) and Cant concentration (Fig. 5b) computed in isopycnal layers (with resolution of 0.01 kg* m^{-3}*), see eq. 7. The* MOC_{σ} *upper and lower limbs can be identified in Fig. 5a, with northward (southward) volume transports above (below)* $\sigma_{MOC.}$ *The vertical profile of Cant concentration averaged in density layers is displayed in Fig. 5b; as expected, we observe a decrease of Cant with increasing depth. The profile of transport of Cant (Fig. 5c) follows perfectly the vertical profile of volume transport. The vertical integration of the diapycnal component of the volume transport (Fig. 5a) is equal to 0 Sv. However, because the Cant concentration is larger in the upper limb of the* MOC_{σ} *than in the lower one (see Fig. 5b),* T_{cant}^{diap} *results in a strong positive value once vertically integrated (see Fig. 3)."*



new Figure 5. T_{cant}^{diap} and the different elements by which it was computed (see equation 7). A) Profile of anomalies of volume transport integrated in density (σ_1) layers with a 0.01 kg m^{-3} resolution. (B) Mean profile of Cant averaged at each density layer. C) T_{cant}^{diap} profile. All the data represented in this figure are the averages of the six surveys analyzed in this work. In the formulation, S means surface and replace the overbar given in equation 7 since in the data displayed there is not vertical integration.

Role of Tnet

The authors mention in the paper a northward volume transport of about 1 Sv over the OVIDE section (p. 16110, l. 2). The paper by Mercier et al. (2013) gives numbers between 2.2 Sv and -0.3 Sv, and these values seem to be used in this work. Otherwise the variability of TCant_net shown in Fig. 3 would not pe possible. This variablity of TCant_net of about 50 kmol/s is not neglible compared to the variability of the total transport of Cant (between 200 kmol/s and 400 kmol/s), but it is almost not mentioned in the paper. Another concern is, how reliable the estimations of Tnet are. Lherminier et al. (2004) give a value of 0.1 +- 2.5 Sv for the net volume transport ofer the OVIDE section in 2004. If this error is applicable to all realizations of the section, all net transports are not significantly different from zero.

The referee is right about the amplitude of the variability in T_{cant}^{net}. Its mean value is 26 ± 9 kmol s^{-1}, northward (and significantly different from zero) as reported in section 4.2. The contribution of the variability of T_{cant}^{net} to the variability of T_{Cant} is discussed at the beginning of section 4.3.1. Because T_{Cant} is not correlated with T_{cant}^{net}, we considered that the variability of the T_{cant} is independent of that term, which seems to be the only conclusion we can draw from our dataset concerning the net transport of Cant.

Variability of MOC on shorter time scales

The paper by Mercier at al.(2013) constructs a MOC index from altimetry and ARGO, and this MOC index has a seasonal amplitude of 4.3 Sv. Given that, how characteristic are the Cant fluxes calculated in this paper for the period between the cruises? A discussion of that topic is completely missing.

The referee is right; there is an intra-annual variability in the MOC that affects the intra-annual variability of the transport of Cant. The data analyzed in the paper were measured during summer months, just when the intensity of the MOC_σ presents its minimum at the OVIDE section (Mercier et al. 2013). Therefore, we could expect that the annual mean value of transport of Cant would be higher than the figures presented in this work. We already indicated in table 2 that our data correspond to summer surveys. Besides, in order to make it clearer, this information has been included in the abstract and the following paragraph has been introduced in the discussion section of the revised manuscript:

"It is well known that the MOC_σ presents a high seasonal variability, for example, Mercier et al. (2013) showed that it has a seasonal amplitude of 4.3 Sv. The data analyzed in this work were measured during summer months. Mercier et al., 2013 show that the MOC_σ at the OVIDE section presents its yearly minimum in summer, but their results also show that the interannual variability of the MOC_σ can be reliably represented by summer data. Therefore, we expect that the interannual variability of T_{cant} is well captured by our study although the magnitudes given in the present work are likely to be weaker than the annual means."

SPECIFIC COMMENTS

p. 16109, l.5
it is not mentioned that V0 and Cant0 have to be substracted before calculating <v> and <Cant>.

The referee is right, although with the new formulation it only concerns the velocity. Accordingly, we have better explained it in section 3 of the revised manuscript:

"where $v = V(x,z) - V_0$, V_0 representing the section-averaged velocity corresponding to the net transport across the section."

p. 16109, l. 10, Eq.(4)
The overbar over 'rhoV0Cant0' is missing.

No, in this case the overbar is not missing because V_0 and $Cant_0$ correspond to the section average value of velocity and Cant respectively. However, with the new formulation the overbar now appears over <Cant>(σ). What was missing in the first manuscript is the 'Area' together with V_0 and $Cant_0$ in order to get a transport of Cant.

p. 16112, l. 21-23
'... on a given isopycnal in the WEB and the IAP, the surface layers are less rich in Cant than in the Irminger Sea (Fig.2).' This is somehow misleading, as the surface waters in the eastern part have even higher Cant values than in the Irminger Sea. The surface waters in the Irminger Sea have the same density as intermediate waters further east, and these are indeed lower in Cant, but this is not a comparison between surface waters. This is more correctly formulates in the discussion section (p. 16119, l. 8-10).

We totally agree, this sentence has been modified in the revised manuscript by: *"Indeed, the shallow isopycnal layers in the Irminger Sea are richer in Cant than the same layers found deeper in the Western European Basin (WEB) and the Iberian Abyssal Plain (IAP, see Fig. 2)"*

p. 16113, l. 4/5 and l. 24-28
in l.4/5 it is stated that the waters (in the Irminger Sea) of the upper and lower lobe have a high concentration of Cant. In l. 24-28, about the waters of the lower lobe the opposite is said, i.e 'these deep and bottom waters are quite diluted when arriving at 60_N, ... resulting in a negative Cant anomaly'. In my opinion the deep waters in the Irminger Sea have an intermediate Cant concentration, i.e. lower than the surface waters, but higher than the old AABW in the eastern part of the OVIDE section, see my general comments.

Yes, the referee is right as we have explained in the general comments. Anyway, lines 24 to 28 do not appear in the revised manuscript as they do not make sense in the interpretation of the new vertical profiles obtained after applying the new formulation.

p. 16119, l. 11-14

'... supporting the idea that deep convection in the Irminger Sea (Bacon et al. 2003; Pickart et al. 2003) reached depths down to 1000 - 1500 m in the 2000s.' Both cited publications deal with data from the 1990s, so their results belong to the 1990s, not to the 2000s.

Yes, the referee is right about the date. Using those references we wanted to support the idea that ventilation of intermediate waters in the Irminger Sea is possible. However, we accept that introducing these references the message is not what we wanted to say, so, this sentence has been replaced by:

"The high Cant content in the intermediate waters of the Irminger Sea is likely due to the recent ventilation of these waters. Indeed, Vage et al. (2009) observed a 700m-deep mixed layer in winter 2007-2008."

p. 16119, l. 18

Why does the LSW yield a minor contribution to the TCant_isop? In my opinion the main reason is the fact that the main formation area of LSW, the Labrador Sea, is south of the OVIDE section. A net northward flow of LSW over the OVIDE line cannot penetrate over the sills to the Nordic Seas, so this Cant has to be stored in the area between the OVIDE line and the sills towards the Nordic Seas. Obviously, this storage rate is not very large.

Using our data we cannot identify the formation area of any water mass. In the discussion we tried to give arguments with appropriate references in order to explain our results. If we consider the argument of the referee, there would be a positive anomaly of Cant in the LSW in the Irminger basin. On the contrary, we have observed a minor contribution of the LSW in the T_{cant}^{isop} due to the small Cant anomaly observed in the LSW. In any case, we do not reject the argument of the referee but it does not explain our result.

'the Tcant' is often written in the paper; I would use Tcant without article (but I am not a native speaker).

Thank you for this comment. We have consulted a native speaker. Following his advices, we have removed 'the' all along the manuscript when T_{cant} is a noun, but we have left it when T_{cant} is an adjective, when necessary.