

Interactive comment on “Deep ocean exchange with west-European shelf seas” by J. M. Huthnance et al.

J. M. Huthnance et al.

jmh@pol.ac.uk

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We thank the referee for their constructive comments (shown in “quotes”).

“General comments: Huthnance and coauthors present a review of the processes affecting the deep ocean - shelf exchanges of water in the west European sector. Their main result is a budget of these exchanges, by region. Experimental and modeling results are used, some from the authors, others from the literature. The physical processes involved in exchanges have already been described by the first author in a review paper (Huthnance, PO1995) and this paper is also a geographical extension of his work during the OMEX Project (Huthnance_et_al, JMS2002). This study also touches

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upon nutrient and carbon fluxes, of great importance in present climate studies, as the role of shelves and coastal areas is now under intense scrutiny.”

No response required.

“Overall, this discussion paper is correctly doing its assigned job, although perhaps there could be more new “substance” (there are only four figures, see below).”

As in response to J. Simpson, we replace Figure 2 by “Schematic of stratification and cross-slope exchange processes” (more processes than in the original). We also introduce figures “Elements of shelf-sea carbon budget” and “Sea-surface temperature off Iberia”, the latter showing upwelled water and filaments. Regarding “substance” see specific responses below.

“I was somehow pondering over the fact that the same authors have currently in press (Huthnance, 2009) or in preparation (Holt et al, in preparation, 2009) two papers about the same subject: I had not access to these two papers, and was wondering how much intersection there could be between the three papers.”

This is a valid point. There is considerable intersection between the present text and Huthnance (2009) which includes an outline of exchange processes and some description of the sectors 6.2 to 6.9 here (5.2 to 5.9 in revised version). [Huthnance (2009) omits West Iberia and the North Sea, but includes the English Channel and Irish Sea as distinct entities, and the Faroes, Iceland and East Greenland shelves]. This is an outcome of the contexts in which the two were written: SCOR working group “Deep Ocean Exchange with the Shelf” here, and LOICZ-JGOFS “Continental Margin Task Team” (CMTT) in the case of Huthnance (2009). Unfortunately the CMTT publication process has been very slow. It was refereed (some years ago) but will appear in a one-off book so to that extent is “grey”. Huthnance (2009) has much more emphasis on measured concentrations and fluxes of nutrients and carbon. It does not (could not) include anything from the modelling (Holt et al., 2009, Wakelin et al. in preparation). These papers are only summarized briefly in this short review. Here (in the revised

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version) there is more discussion of the distinction between summer and winter and there will be some account of interannual variability.

"I was also wondering if the review of physical processes was exhaustive enough: Could there be other mechanisms? "

This is hard to answer! Everything relevant in Huthnance (1995; loc. cit.) is mentioned.

"Or could there be interactions between the various processes?"

This is a valid point. The answer is "yes". It is discussed briefly in section 7 (section 6 in the revised version) in relation to the values in Table 1 and whether the individual estimates should add to the total. This discussion is expanded in the revised version.

"Could seasonality be of importance in places other than off western Iberia?"

Certainly. In particular, the internal tide contributions in Table 1 apply only in summer. Winds tend to be stronger in winter as shown in an expanded Table 1. We will expand the modelling estimates to separate summer and winter for each modelling sector in figure 3. We have added mention of distinct summer and winter across-slope transport indicated by drogues west and north of Scotland (Burrows and Thorpe, 1999).

"What about interannual variability? Can this be evaluated by some kind of indices?"

There are only a very few measurements to estimate interannual variability in cross-slope exchange. In principle it would be possible for winds, for the slope current in two sections (west and north of Scotland), and possibly for eddy and filament statistics (where relevant). The latter certainly are very variable year-to-year. Inter-annual standard deviation could be an "index" and will be added for the figure 3 model calculations of ocean-shelf fluxes.

"Could this be an avenue to give more "substance" to the manuscript?"

Yes, as above.

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"Specific comments: p.1062, l.4: "associated filaments off Portugal and north-west Spain": what about filaments in other regions?"

There is no developed upwelling elsewhere. "Overshoot" of the along-slope flow at Goban Spur is mentioned. Otherwise there are meanders and eddies as discussed, but filaments are not known.

"p.1068, l.2: "Warm, saline North Atlantic Water (NAW) forms a poleward current": Is it always poleward? what about equatorward reversals?"

There are occasional reversals but drifters especially (as in Pingree et al., 1999, Burrows et al., 1999) show consistently poleward progress when over the slope.

"p.1068, l.3: "The current is approximately barotropic": Is there experimental evidence to support this claim? Would you have references?"

Yes and yes. We have added references Huthnance (1986: The Rockall slope current and shelf-edge processes, Proc Roy Soc Edinburgh, 88B, 83-101) "and references therein", and Pingree and LeCann (1989, 1990, loc. cit.). The citation (already) of Frouin et al. (1990), Pingree et al. (1999), Souza et al. (2001), McClimans et al. (1999) and Skagseth et al. (2004) is meant to indicate experimental evidence.

"p.1070, l.1-3: "Large-amplitude (non-linear) internal tides can transport as much as 1m²/s...": Is this really substantiated by measurements? Would you have references?"

Yes and yes. In the revised version the estimates are distributed to the respective sector texts and references are given. [The original was here referring to the Celtic Sea and an estimate in Huthnance (1995) based on soliton amplitude and length in Pingree (1984)].

"p.1072, l.22-23: "These features are illustrated by tracer distributions in Fig.4": Some more comments on this figure perhaps?"

The following has been added to the text. "The figure shows some tracer advance

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or entry of Atlantic water on to the shelf south-west of the UK and subsequently into the English Channel, on to the shelf west of Scotland and in to the northern North Sea both west and east of Shetland; there is a marked tongue along the west side of the Norwegian Trench. Tracer also advances over Porcupine Bank west of Ireland and there is a clear tongue representing the poleward slope current around Scotland. Strong tracer concentrations at 24 months south-west of the UK confirm the lack of off-shelf transport in this sector. [Elsewhere the off-shelf picture is more complex as reduced tracer values can derive from the various banks west and north of Britain].” If time permits we may be able to quantify the amount of tracer within the 200m contour at 6 months and 24 months to compare with figure 3.

“p.1073, l.9: “in winter, (north-) westerly prevailing winds give mixing and downwelling”: What about south-westerlies? Do you get downwelling with “(north-) westerly” winds?”

It is true that prevailing winds are westerly or north-westerly and that on average the winds favour downwelling and indicated by the NOAA calculation of downwelling index tabulated in Huthnance et al. (2002). However, we agree with the referee: winter winds are variable and there can be south-westerlies which would also give downwelling. This has been rewritten as “in winter, winds are variable and upwelling can happen in any month, but (north-) westerlies prevail and give mixing and downwelling on average (NOAA upwelling index values analysed in Huthnance et al., 2002)”.

“p.1079, l.3: “may not be continuous”: Do you mean in space and/or time?”

In space is intended. We rather lack evidence around SE Biscay. Revised text is augmented as: “may not be spatially continuous, e.g. there is less evidence for it around south-east Biscay”.

“p.1079, l.6-7: “relatively small exchange in eddies”: Is this really substantiated? Do we really have the experimental data supporting this claim? Could it be strongly intermittent?”

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Yes (but only in some sectors), yes and yes. The statement has been qualified “except in the north”. The values for the west Iberia and south Biscay sectors in Table 1 are substantiated by revised sections 5.1, 5.2. The north Scotland and Norway estimates are more speculative but limited by integrity of the slope current in these sectors. Text to this effect has been added in the north Scotland and Norway revised sections 5.7, 5.9. The south Biscay eddies in particular are intermittent, reducing their contribution to exchange.

“Do you think it would be possible to put error bars on the figures given in Table 1?”

This is difficult in practice. Even in principle error bars will be less if the values are for a longer time-average. All the processes in Table 1 can be zero for varying periods of time. We have added distinct summer and winter values for winds, and the average standard deviation of mean monthly values within those periods. As above, we plan to add the inter-annual standard deviation for the figure 3 model calculations of ocean-shelf fluxes by sector.

“Technical comments: p.1067, l.4: “3-d physics-only model with 12 km resolution”: Is 12 km resolution enough to correctly describe multiple physical processes at the shelf-slope-ocean transition, where topographical scales are O(few 10s km) or less?”

We have found that where the slope is steepest, resolution finer than 12 km improves representation of the slope current and is necessary to represent internal tides correctly. For the processes tabulated in Table 1, wind-driven exchange should be correctly modelled, the internal tide will not be, the slope current may be too broad (extra transport) but should have the right velocity and hence transverse exchange. The resolution is marginal for eddies north of Scotland, and Goban Spur “overshoot”; Figure 4 shows that such features occur but they may be “permitted” rather than properly resolved.

“p.1068, l.14 and Fig.2: Although there are only four figures in this manuscript, do the authors think that this Figure 2 is really necessary? Furthermore, this Figure is already

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in Huthnance, PO1995.”

In lieu of the previous Figure 2, Huthnance (1995) is now referred to. As in response to J. Simpson, we replace Figure 2 by “Schematic of stratification and cross-slope exchange processes” (more processes than in the original). We also introduce figures “Elements of shelf-sea carbon budget” and “Sea-surface temperature off Iberia”, the latter showing upwelled water and filaments.

“p.1069, l.26: Should it really be “cyclones”?”

This must be referring to p. 1068. Yes, cyclones (as distinct from anticyclones). Not tropical cyclones of course.

Interactive comment on Ocean Sci. Discuss., 6, 1061, 2009.

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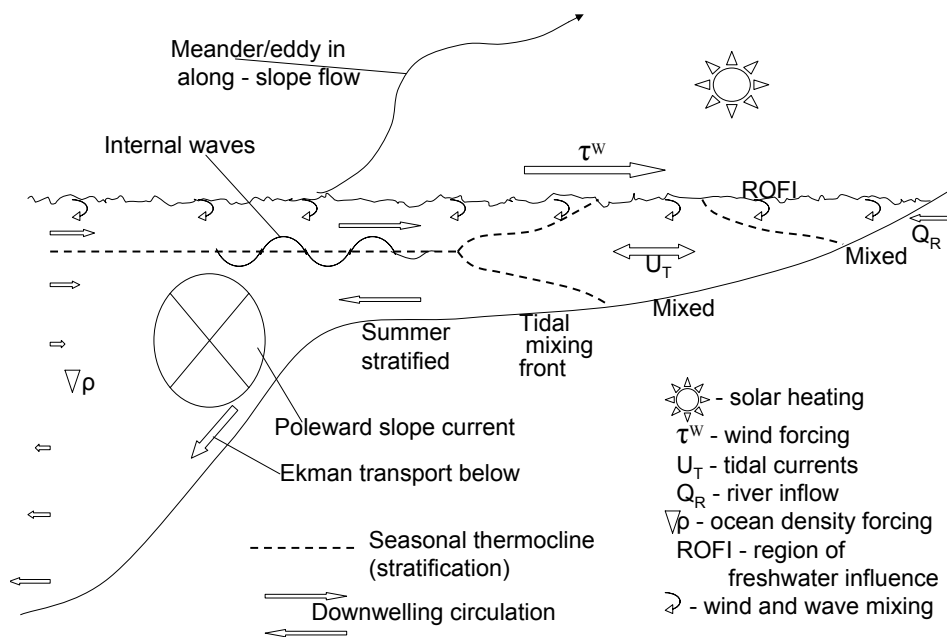


Fig. 1. Figure "Schematic of stratification and cross-slope exchange processes"

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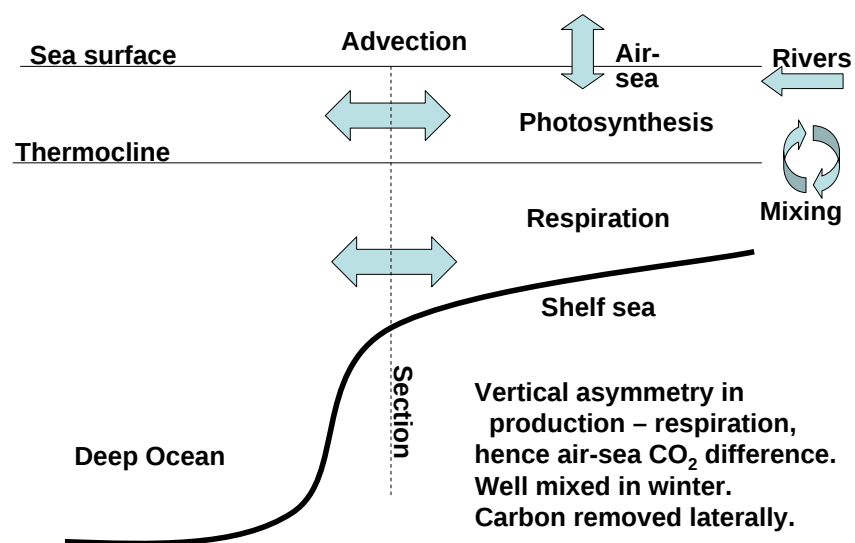


Fig. 2. Figure "Elements of shelf-sea carbon budget"