Paper os-2011-68 Response to reviews

Martinson and Mckee, Transport of warm upper circumpolar deep water onto the Western Antarctic Peninsula Continental Shelf

Our response to reviewer comments is provided here — reviewer's comments are italicized. I have added a second author (previously acknowledged, as developing all of the methods for identifying eddies) given the reviewers comments: Darren C. McKee.

Reviewer #1:

1) The weakest part of the paper is the introduction, which is restricted to one short paragraph. A brief description of the physical oceanography (water masses, stratification, and circulation) of the region as documented in earlier work would go a long way to addressing some of the questions that follow.

We have added a couple of lines to the Introduction regarding the ACC and UCDW. However, regarding the addition of the physical oceanography description, we have expanded this (as per your request) but have left it as the section immediately following the Introduction. For us, that organization contains all the information you seek, but separated it into a structure I still prefer — that is, the Introduction sets the motivation and goal of the study; all other sections naturally follow that. I suppose, if you felt overwhelmingly strong about this, we could re-label section 2.1.1 (Physical Setting) as a subsection of the Introduction.

2) In particular it would be helpful to clarify the water mass definitions and justify the exclusion of LCDW from consideration, particularly given that earlier studies of CDW intrusion onto the WAP shelf have identified both UCDW and LCDW intrusions. The derivation of the UCDW fraction shown in Figure 3 could be clarified at this point. I appreciate that it is explained in MSISV08, but it is important for the interpretation of Figure 3. Critically one end-member of the "three water mass mixture" is so dense that it could never contribute directly to the mixture of waters on the shelf. This gives a bias towards high fractions of UCDW. For example, using this system classically-defined LCDW becomes something like 80-90% UCDW and 10-20% DW. However, LCDW is a water mass in its own right and is not formed by mixing between the two end members. Wouldn't it be more appropriate to take WW, UCDW and LCDW as the end members for the shelf waters? That would give generally lower fractions of UCDW. It would not alter the basic pattern, but it would highlight the point that UCDW intrusions may not be the whole story, and that other waters derived from the ACC contribute to the water column over some parts of the shelf.

See response to comment 4 below (also dealing with Figure 3).

3) While these may seem like pedantic points, they would contribute important clarification of how this work relates to earlier studies. Without that clarification, the last sentence of the abstract, for example, read like a contradiction to me. Even after a complete first reading of the paper I remained unclear as to whether the findings supported or refuted earlier studies. Apart from the subtleties of the water mass definitions, I missed the meaning of the term "nominal shelf", which occurs twice, almost unnoticed (by this reader) in the paper. This is not a standard term I know of, which is why I missed the critical information that it apparently conveys, but I think it means the expansive, relatively shallow shelf regions outside the deep cross-cutting troughs. This is a critical point that needs to be made much more clearly, because much of the interest in the oceanography of the region (from a climate change/sea level perspective) is focused on the water properties within the troughs, since these lead to the grounding lines of the ice shelves. So many readers will assume that a discussion of the processes that fill the troughs will

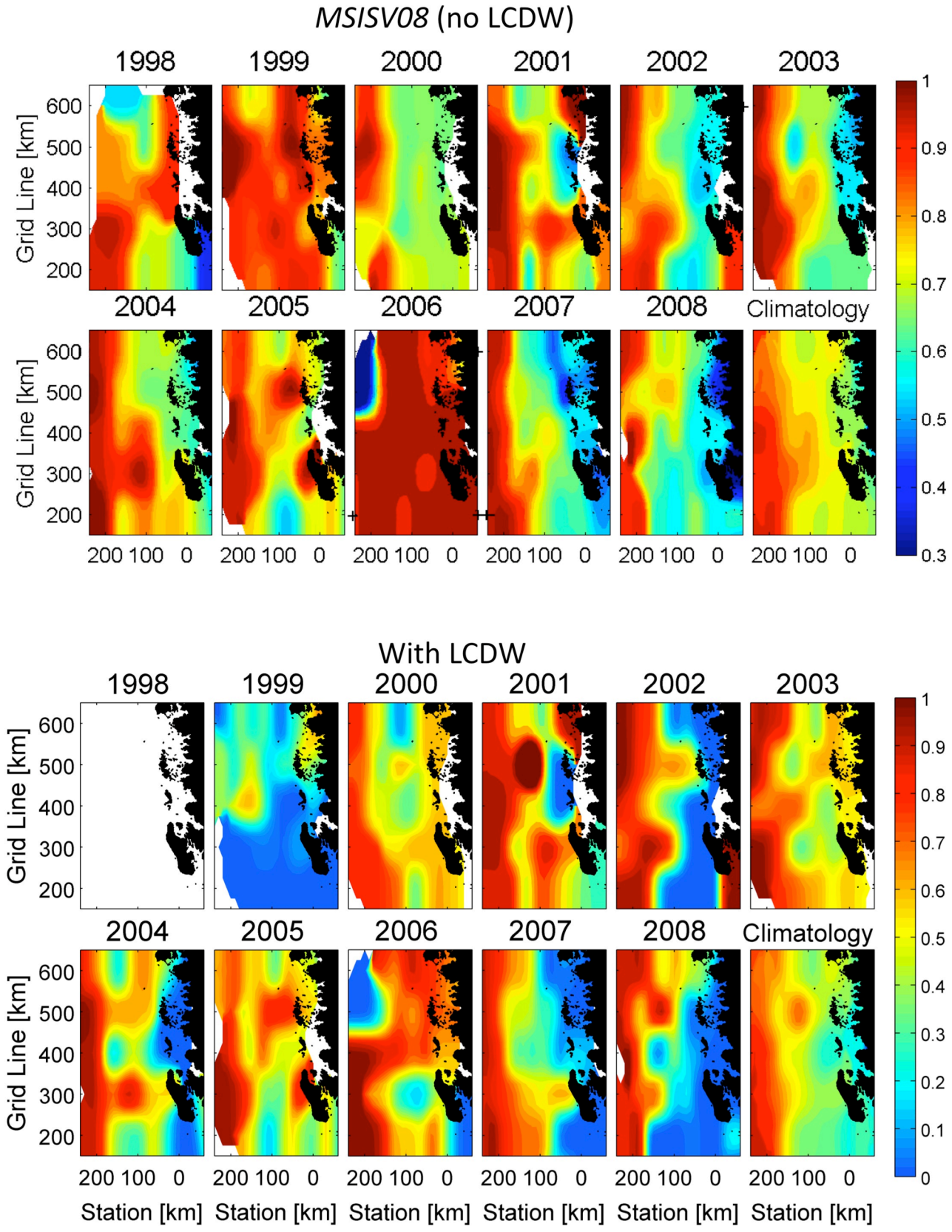
be part of the paper. In fact they are not. Troughs are only considered as possible sources of water that spreads onto the "nominal shelf". The processes by which the troughs are filled with water from the ACC, and the water masses that fill them, are not discussed.

I have clarified how results from this study relate to conclusions of upwelling in MSISV08 (addressing your contradiction in the abstract) and meaning of "nominal shelf". You are correct about my focusing on how UCDW enters the shelf waters above the troughs, where the biology/ecosystem is most active. I have made this more clear, since water entering the troughs has received some very good study.

4) Something that would help is a more in-depth discussion of Figure 3 (presently only mentioned in passing) as background and motivation for the study. The moorings are focused in the region of high UCDW fraction. This is fair enough as UDCW is slightly warmer and of biologically greater significance (?) than LCDW. However, UCDW is found in mid-water-column, directly below the main pycnocline and well above the seabed, even outside of the troughs. The study was presumably motivated by the desire to understand processes affecting the mid-water column and as a result can give no information on what waters occupy the deeper parts of the shelf, or how they get there. All of this may be self-evident to those more familiar with the WAP and the Pal LTER data (and the underlying motivations for that work), but the paper should be readily accessible to a wider audience. At present the exclusive discussion of UCDW as the dominant water mass everywhere on the shelf might suggest to a non-specialist that the processes discussed could account for all the warm waters on the shelf.

We agree with your comments, and have added LCDW to the property matrix. MSISV08 had excluded LCDW (as stated in that paper) because its inclusion led to what we considered too much need for the inequality constraints — typically a sign that the model being fit is incorrect or the property matrix is poorly defined for the constituent water masses. The new result and original (no LCDW) result are shown in the included figure. As you deduced, the overall patterns are similar and fractions of UCDW are reduced. The patterns still show Line 300 with UCDW on the shelf, maintaining the reason for locating moorings here. Given that this particular figure serves only the purpose of showing one piece of referenced evidence for the location of the moorings, we have removed it completely. The discussion now simply states that the SO GLOBEC and MSISV08 work suggest placing moorings in the locations we chose (which is still true given the new OMP results). Your comment has encouraged our reassessment of LCDW; it is clearly important here while not altering our conclusions about how UCDW enters the shelf and we appreciate it.

As stated above, we have also expanded the discussion of water masses on the shelf, making it clear that UCDW is the water mass of interest in that it that is the warmest water and has the highest concentration of nutrients for the biology.


MSISV08 (no LCDW)
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Climatology
Grid Line [km]
600
500
400
300
200
200 100 0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
With LCDW
Station [km]
0.2
0.1
0

5) In section 3 a large section of the text is devoted to the identification of eddies, while very little is devoted to alternative processes. This is to some extent inevitable, given the relative complexity of the analyses. For example, comparatively simple arguments are used to dismiss processes 2 and 4. However, I did not really follow the discussion of upwelling, and this section really needs some extra clarification. What is meant by a period when "mass balance was approximately achieved"? Is it reasonable to expect that currents are constant over 400 km? When you talk about upwelling you mean uniform off-shelf transport in the upper layer and a corresponding uniform on-shelf flow at depth? You are not looking at local convergence/divergence in the near surface flow? But if the currents really were constant over the shelf, wouldn't you see "lagged coherent events in Q(t) across the entire mooring array"? The lack of such events is used to eliminate "shelf-wide flooding" in the following section.

We have modified the discussion as suggested. In particular, we have dropped the failed ADCP upwelling discussion and clarified the implications of the eddy findings to our previous upwelling conclusions of MSISV08 (addressing the "apparent contradiction" in the Abstract in your comment #3). We have given more attention to the other mechanisms (starting with better definitions that come from Reviewer #2's suggestion to review previous literature about those other mechanisms).

6) Many of the figures would benefit from being reproduced at a bigger scale with larger fonts.

This is a good suggestion and has been done for all figures.

Reviewer #2:

1) I found the discussion of the mechanisms listed in the abstract to be too brief and incomplete. Given that this seems to be the first time all these mechanisms are discussed in the same paper, a complete summary of the available evidence is warranted. One key aspect here is the "or assumed" parenthetical in the abstract. The reader should be given a clearer picture of which mechanisms have already been shown to be present, and the relative strengths of the evidence to support each of the other ones.

We have now made better definitions of the other mechanisms from previous studies, including a summary (as requested) in the main text. This eliminates "or assumed" in the abstract (abstract rewritten to accommodate the new information).

2) "Eddies at that site are not investigated since this study focuses on how the UCDW enters the shelf from the ACC waters over the slope." This seems like a regrettable omission, given that there is very little or no published studies using moored data from that area. It is a rather interesting observation that the eddies at this location seem to show similar properties as those found in Marguerite Trough - although with fewer eddy events. This should be fully explored, as the previous studies, both observational and model-based, have concluded Marguerite Trough as a preferred path for this warm water intrusions to move across the shelf, but there's very little data from moorings outside Marguerite Trough itself. Completing the eddy analysis for the other moorings that show eddies should be included in a revised manuscript.

We are presently working on a second manuscript to address eddies at each of our mooring sites, but prefer to stay focused in this paper on the single issue of how UCDW enters the shelf in the study region. We have also made it more clear that we are interested in how UCDW is transferred into the shallower waters of the shelf (above what we call the nominal shelf depth — now explained as per Reviewer #1 request). The water above the nominal shelf floor influences the main biology and ecosystem of the WAP, hence our focus of water outside of the trough,

which has been well studied as you mention (and we clearly state in the paper).

3) Please include the water mass involved. Also, the analysis should include LCDW intrusions, as again there have been very few studies of this, and they show that UCDW and LCDW intrusions are rather different in nature.

We now include a discussion of all water masses present in the region (including LCDW). Unfortunately we are unable to assess LCDW's role in intrusions given the current configuration of our moorings (with no salinity sensors).

4) The analysis in Section 3.3 seems weak. There data simply doesn't seem to be appropriate to carry out this kind of analysis. Was the ADCP data detided? What about inertial frequency and other high-frequency variability? More importantly, it is unclear how the "upwelling heat flux" is calculated from the simple mass balance argument that precedes it. I would recommend simply removing this section and, if this mechanism is to be retained as a possibility, saying that there is no data to evaluate it at this point.

We have eliminated this discussion and state our inability to evaluate upwelling as you suggest.

5) A number of "minor" comments are listed.

We have addressed each of these.