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Ocean Science Discussions

Interactive comment on "Rapid subduction in the deep North Western Mediterranean" *by* J. A. Aguilar et al.

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Reply referee 1 (D. Smeed)

We thank the referee for the comments raised.

Ad 1). The large vertical velocities are not unusual. Vertical velocities of the same order of magnitude (and even larger) have been observed by Schott et al in the 1990s in their search for dense-water formation evidence (see the review by Marshall and Schott, Rev.Geophys.1999 showing some of these data). Similar vertical current magnitudes have also been observed by van Haren et al GRL2006 below Algerian eddies, where they were persistently downward over several 100s of m. Prior to that paper an extensive data-error analysis was made, showing: virtually no tilt of the sensors (<0.5

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Interactive Discussion

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degree to the vertical) and no correlation with horizontal motions. In the present data, tilt is a bit larger (2-3 degrees; Figure attached) and seemingly there is a correspondence with the horizontal current. Of course, if a bias in tilt sensors exists it is unknown to the user, but there are several tests that can be and are performed in the data analysis. One is computing cross-correlations. These did not show significant coherence between vertical currents (w) and tilt or horizontal currents. This non-significance is also confirmed from detailed regard of the time series, which show ambiguous correspondence between the data: sometimes there is correspondence, sometimes not. If the vertical currents were largely attributable to 'false', biased tilt sensors, they should certainly show correspondence of w with horizontal currents at the inertial frequency, which is a ubiquitous horizontal motion in the Mediterranean. However, the spectra of these current components are completely different (cf van Haren and Millot, GRL2005). In the same paper it is also shown that the two have different behaviour, as is expected for internal waves in alternating stratified and homogeneous waters. The spectra of the present observations show the same characteristics as those in the above paper. As an indication for the disparity between horizontal and vertical currents, please consider the lower panel of the attached figure, in which the observed vertical current is shown (blue) and a fictitious vertical current computed from the observed horizontal current using the tilt of the upper panel (which is fairly constant with time, as if a bias). It is clear that on the large scale the two records are at odds, but also that the observed vertical currents seem more noisy. This 'noise' is internal waves, which would never appear from an effect of a horizontal current biasing through a wrong tilt sensor. All corrections are made directly by the instrument (incorporating also the heading which varies slowly with time, see Figure) and not during post-processing. This is the only appropriate way of doing so for an instrument moving in space and storing ensemble averages of data from more than one acoustic ping: averaging should be done in a Cartesian coordinate system, which the acoustic beams do not encompass. We conclude that the data are genuine vertical currents, with a worst case maximum bias of 0.003 m/s (van Haren et al GRL2006). This is more elaborated in the text now. A last remark about the error

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velocity: indeed it is calculated in a coordinate frame fixed to the instrument, but as an error estimate to w it is valid for all coordinates because the error velocity results from a subtraction of beam pairs.

Figure: upper panel: pitch (blue) and roll (green) tilt-sensor data; middle panel: compass-heading; lower panel: observed w at 15 m below the ADCP (blue) and w inferred from horizontal currents at the same depth and tilt sensor data (red).

Ad 2) As mentioned above such downward current speeds have been observed before and, indirectly, some inference can be made from fresh materials that were found in the deep (typically 1000-2000 m) by Heger et al DSRII2008 and unexpected large fluxes of PAHydrocarbons (Bouloubassi et al MarPollBull 2006). Such materials could be traced to originate from the surface and, judging from there 'freshness', should have arrived in the deep in a few days. The bottom is fairly flat, but large-scale topography is nearby, as indicated. Possibly the model quoted by the referee is also not valid for the case of present data, as it would probably be not valid to describe large vertical currents in smaller-scale chimney-like convection, also related with small-mesoscale eddies. The Ligurian Sea and the Northern Current are vigorous systems (cf Crepon et al, 1980's; Taupier-Letage and Millot OA1986). Perhaps other models should be used?

Ad 3) The bottom is fairly flat, some small-scale bumps occur with about 10 m height variation over the entire array of moorings, but large-scale topography is nearby: the continental slope is about 10 km away. As mentioned above, there seems a correlation between horizontal and vertical motions, and there is occasional correspondence indeed, which is logic near a slope, but also logic near or below eddies. Overall, the correspondence is not statistically significant. The relative uniformity of vertical (and horizontal) current (and echo) over the vertical is more related to the uniformity of (near-homogeneous) stratification.

Ad 4) As will be elaborated in the revised text, the effect of cascading is dismissed, after quite some debate, for the following reasons. It has been dismissed by Khripounoff et

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al, MG2009 in their current observations in the Var-canyon, because flash floods last only a very short period (less than a day) and the characteristics they found of the sediment resuspended in the deep were different from those higher up the canyon. Even for resuspension in the deep canyon, they found more evidence for influence of the Northern Current than from flash floods. Var-canyon is nearest to and up-stream of ANTARES. It has been dismissed as an explanation for the present observations, after showing the data to canyon specialists A. Vangriesheim (Ifremer Brest) and P. Puig (Univ Barcelona). Finally, the data have been compared with recent canyon data (X. Durrieu-Madron). As mentioned, there might be some direct effects of deep-water formation in March in the present data, but canyon cascading or dense-water formation cannot explain the present data later in the year, which have a periodicity of about 20 days that is typical for the meandering of the boundary current. Of course, except for internal waves near the buoyancy frequency and homogeneous turbulence, vertical currents are generally weaker than horizontal currents in the ocean. But below eddies and in convective zones they can also be relatively strong; topography is not the only source for strong vertical currents.

Interactive comment on Ocean Sci. Discuss., 7, 739, 2010.

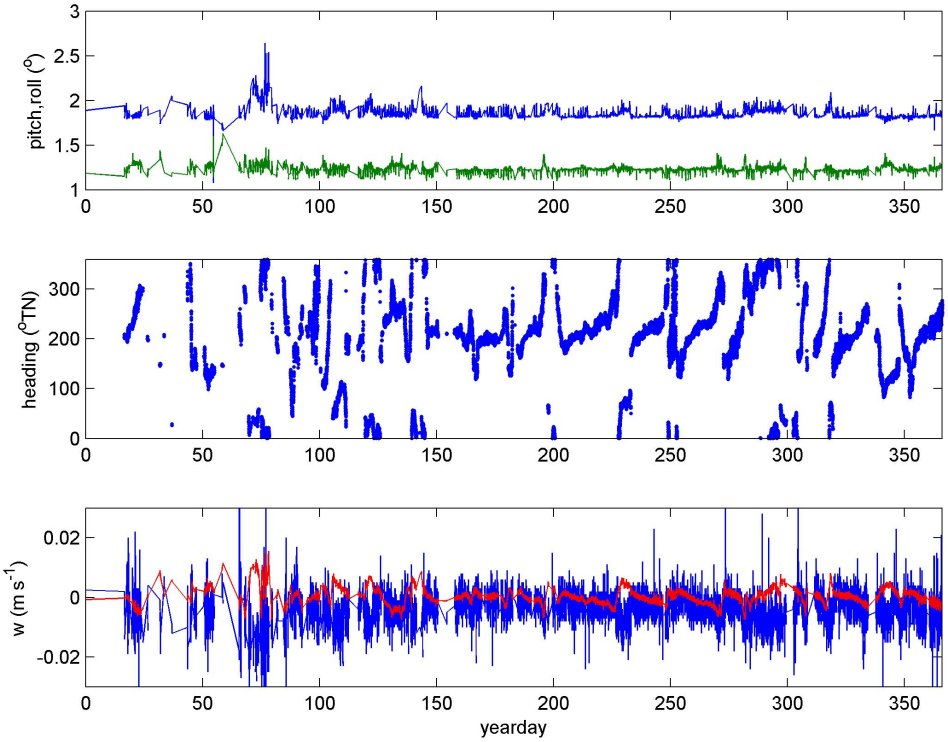

Fig. 1.

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