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Ocean Science Discussions

Interactive comment on "Stochastic heterogeneity mapping around a Mediterranean salt lens" *by* G. G. Buffett et al.

G. G. Buffett et al.

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Dear Editor, Ocean Science

The authors thank anonymous reviewer #3 for their contribution to this manuscript. They suggest an improvement to the manuscript that would further its interest in the physical oceanographic community.

We address their comments below by following their recommendations thereby substantiating much of the interpretation of seismic data with reference to internal waves and to oceanographic properties at the boundaries of meddies (where the stochastic heterogeneity mapping was applied). In addition we have briefly included a description (and in depth references) of the multi-channel seismic (MCS) method. To this end, we

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have made minor revisions to the text.

Sincerely,

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Interactive comment on "Stochastic heterogeneity mapping around a Mediterranean salt lens" by G. G. Buffett et al.

Anonymous Referee #3 Received and published: 8 February 2010

General comments: The manuscript "Stochastic heterogeneity mapping around a Mediterranean salt lens" by Buffett et al., addresses an interesting topic within the scope of Ocean Science: the study of fine-scale thermohaline structure around an eddy of Mediterranean Water origin. The approach was to apply a stochastic method to water-column seismic reflectivity data and extract information about signal heterogeneity and lateral scales. The paper is interesting, clearly presented and certainly deserves publication since it presents new data and a new method to study oceanic small-scale processes. I have only a general comment that the authors might consider when revising the manuscript. Since the aim was to estimate internal wave scales, I'm nevertheless concerned that almost no effort was put into showing how the acoustic signal relates to the ocean density structure. Could the authors show some in situ validation, if and where available, so as to build understanding about the reflectivity patterns seen in Figure 2? How well undulations of reflectors really match isopycnal displacements? The authors focus in detail three different regions around the eddy. Little is however said about the physical processes occurring in those areas and how they impact on the acoustic signal, what could definitely interest the oceanographic community.

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The purpose of this paper was to investigate stochastic heterogeneity mapping on an already processed seismic section. For reasons of concision we did not elaborate on the details of seismic data acquisition and processing. However, briefly, after acquisition of the seismic data, a processing scheme is followed to generate a 2D profile of the ocean and to increase the signal-to-noise ratio. Such a scheme is heavily dataset and personnel dependent. It involves sorting of the data traces in a geometrically suitable way, the correction for 'normal moveout', frequency filtering, noise reduction, stacking (summing together of adjacent traces) and migration, among other auxiliary processes. Knowledge of the details of seismic reflection profiling makes clear the relationship between the density structure of ocean and how this is represented in the seismic data. We agree with the reviewer that this is critical to the interpretation of the data, but as a complete discourse of seismic data acquisition and processing is well outside the scope of this paper (our method operated on already processed seismic data), we refer the reviewer to two sources (these references are now properly amended to the manuscript giving the reader a better opportunity to familiarize themselves with multichannel seismic (MCS) reflection profiling):

For an introductory treatise on the principals of the MCS method, in particular with respect to physical oceanography, we recommend the recent article:

Ruddick, B., H. Song, C. Dong, and L. Pinheiro (2009), Water column seismic images as maps of temperature gradient, Oceanography, 22, 192– 205.

For a more complete discussion (while there are many available) we recommend:

Yilmaz, O., 1987. Seismic Data Processing, Soc. of Explor. Geophys.

In the text, however, in accord with the concerns of the reviewer we have justified the use of seismic reflection profiling to image the density structure of the ocean by stating:

The recorded seismic signal is proportional to ocean density stratification. That is, acoustic impedance boundaries, which are what give rise to the reflectivity as revealed by the multi-channel seismic (MCS) method, are expressed as the product of in-situ density and sound speed. Density and sound speed, in turn are functions of the relative proportions of temperature and salinity of the reflecting interface [Sallarès et al. 2009].

Regarding the physical oceanographic processes occurring at the boundaries of meddies (the areas of analysis), we have also elaborated more, citing:

Biescas, B., V. Sallarès, J.L. Pelegrí, F. Machín, R. Carbonell, G.G. Buffett, J.J. Dañobeitia, and A. Calahorrano (2008), Imaging meddy finestructure using multichannel seismic reflection data. Geophys. Res. Lett., 35:L11609, doi:10.1029/2008GL033971, 2008.

whom analyzed the fine structure of meddies using MCS and

Ruddick, B. (1992), Intrusive mixing in a Mediterranean salt lens – intrusion slopes and dynamical mechanisms. J. Phys. Oceanog., 22:1274–1285.

We have added the following text to the Discussion to help elucidate the interpretation:

Internal waves develop in the ocean when density stratification is disturbed, thereby driving turbulent processes and diapycnal mixing [Garrett, 2003]. The recorded seismic signal is reflected from ocean density stratification. Acoustic impedance boundaries, which are what give rise to the reflectivity as revealed by the multi-channel seismic (MCS) method, are expressed as the product of in-situ density and sound speed. Density and sound speed, in turn are functions of the relative proportions of temperature and salinity of the reflecting interface [Sallarès et al. 2009]. Ruddick [1992] reported that the upper boundaries of meddies are dominated by diffusive convection processes, whereas the lower boundaries are susceptible to salt fingering. Salt finger scales are several orders of magnitude smaller than that directly resolvable by MCS methods (typically, in the tens of centimeter range [Linden 1973]). However, we may expect to detect them indirectly through our estimation of the Hurst number. The reason for this is that the Hurst number is a measure of surface roughness, low Hurst numbers being repre-

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sentative of a richer range of high wavenumbers. As seen in Figure 3, Hurst numbers calculated for the bottom of the meddy are found to be dominated by lower numbers, whereas for the top and sides of the meddy, an absence of these lower Hurst numbers is found. This seems to indicate that, although we can't hope to actually resolve the salt fingers themselves with seismic frequencies, the richer range of high wavenumbers points to the presence of such finer structures at the bottom as opposed to at the meddy's top and sides.

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