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Interactive comment on “Depth dependence of westward-propagating North Atlantic features diagnosed from altimetry and a numerical 1/6° model” by A. Lecointre et al.

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General Comments

This manuscript is an interesting and valuable contribution to the ever-expanding literature on westward energy propagation in the ocean. The authors validate the westward energy propagation in a high-resolution model by comparison of the surface variability with altimeter data and then analyze the model output to estimate the depth dependence of the westward propagation speed. The most intriguing result of the analysis is that the westward propagation speed in the model decreases with depth in most of the North Atlantic. The amount of slow-down with depth varies geographically. The

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authors interpret the results as first-mode baroclinic Rossby waves modified by background mean flow and bottom topography, and argue that the vertically nonuniform propagation speed questions the validity, relevance and accuracy of the usual normal mode assumption of standard linear theory for Rossby waves. The authors suggest that the essentially uniform propagation speed with depth in the Azores Current region is because the variability in this region consists of nonlinear eddies. No rationale is offered for why uniform vertical structure is indicative of nonlinear eddies while nonuniform vertical structure is indicative of linear Rossby waves.

My interpretation of the results in this paper is quite different from that presented by the authors. Evidence is conclusive now that the vast majority of westward energy propagation observed in satellite altimetry that has been (mis)interpreted in the past as linear Rossby waves modified by mean currents and bathymetry is actually nonlinear eddies. Studies of this phenomenon that predated the availability of the merged dataset from the TOPEX/Poseidon and ERS-1/2 altimeters were unable to distinguish linear from nonlinear variability because of inadequate spatial resolution of the SSH field. In the merged dataset, more than 90% of the observed westward propagating features are nonlinear at least once during their lifetimes. When it is accepted that nearly all of the observed variability is nonlinear eddies, there is no reason to expect a priori any particular vertical structure of the features. As discussed by Roemmich and Gilson (2001, *J. Phys. Oceanogr.*, p.675) and many others, the vertical tilt of nonlinear eddies results in an eddy flux of heat.

The vertically nonuniform propagation speeds presented in this paper may therefore be indicative of zonally nonuniform meridional eddy heat flux. If an eddy starts out as with vertically uniform phase and propagates westward with faster propagation speed at the surface than at depth, the eddy would gradually tilt toward the west. As discussed by Roemmich and Gilson (2001), a westward tilt results in northward heat transport. The slow-down of westward propagation with increasing depth would thus result in westward intensification of northward eddy heat flux.

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The stated objective of this paper (e.g., the last paragraph of the Introduction and the first sentence of the Discussion section) is to investigate and describe the vertical structure of westward propagation. However, that is not actually what is presented in this paper. The authors have documented the vertical structure of the propagation speed, not the vertical structure of the variability. The latter could be done from lagged correlation analysis, which would quantify the vertical phase structure of the westward propagating features. This would then provide the information needed to test my hypothesis in the preceding two paragraphs that the vertically nonuniform propagation speed represents westward intensification of eddy heat flux. It is noteworthy that the authors do not present any figures in this paper that show the nature of the westward propagation at any levels other than at the surface. In lieu of lagged correlation analysis of the vertical structure at a few selected locations (or summarized statistically on a regular latitude-longitude grid), time-longitude plots at a few selected depths would allow a qualitative assessment of the vertical phase structure of westward energy propagation along the latitude of the plot.

Because of the importance of physical interpretation of the vertically nonuniform westward propagation speed, I encourage the authors to expand their analysis to investigate whether the slow-down of westward propagation with increasing depth is a surrogate indicator of westward intensification of northward eddy heat flux.

Minor comments

1. p.819, lines 8-11: The authors state that the validity and accuracy of the normal mode expansion is questionable. This is not technically correct. The normal mode expansion is valid and accurate, regardless of its dynamical relevance. The normal modes provide a complete basis set. But just like sines and cosines, the normal mode expansion may not be an efficient representation of the vertical structure of the variability.

2. p.826, line 13: The vertical stripes in the rotated coordinate system are parallel to

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the t -axis, not the x -axis.

3. p.833, lines 18-19: The overall slow bias of 1 cm/s in the westward propagation speeds in the model is an interesting result that is worthy of further investigation. From a WKB analysis, the westward propagation speed of Rossby waves in the nondispersive limit is proportional to the square of the vertical integral of the buoyancy frequency (see Appendix A part b of Chelton et al., 1998, J. Phys. Oceanogr., p.448). The bias of the propagation speeds of the model may thus be due to the stratification being too weak in the model. This could be assessed by comparing the buoyancy frequency profiles from the model with historical hydrographic data.

Interactive comment on Ocean Sci. Discuss., 4, 817, 2007.

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