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Ocean Science Discussions

Interactive comment on "Propagation and dissipation of internal tides in the Oslofjord" *by* A. Staalstrøm et al.

Anonymous Referee #1

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This manuscript describes observations of tidally driven flow in the Oslofjord, largely focusing on 3 different locations, one near the main sill, one further inside the fjord and one outside the fjord. From these measurements, the authors attempt to deduce the phase speed, modal decomposition, and energy budget for the baroclinic tide, and finally estimate the mixing efficiency. The results are interesting and creative, but I have some questions about some of the assumptions and approximations, and therefore recommend revision before final publication.

Specific comments

Estimated energy fluxes: The authors calculate energy fluxes at a single location using a variety of methods, which helps to establish the relative robustness of the results. However, all methods rely on extrapolating from a single point estimate to an integral

flux through the fjord cross section by multiplying by the cross sectional area. Although the authors do not give many details about the area used in this calculation, I assume it is the full cross-sectional area of the fjord at this location? This assumes that the flux per unit area at one location can be extrapolated across the whole fjord, yet there is no evidence that this is the case. For example, the internal tide could have more of a beam-like character in the horizontal, and not widen as the fjord widens. Or as an internal wave beam enters a shallower region the depth integrated flux could remain constant, and then the flux per unit area would be higher in a shallower region than in a deeper region. Can the authors provide some reasoning to back their assumption that the flux at one profile can be extrapolated, and provide some estimate of the possible range of the cross-sectionally averaged flux estimate, given these uncertainties?

Dissipation estimates: This is the weakest part of the paper, in part because of the extrapolation made earlier for the flux calculation, and also due to additional poorly justified assumptions. For example, in equation 18 you propose that the baroclinic energy flux at S3 is equal to twice that at S5 (where you have measurements). This does not seem to be to be a good approximation - firstly, dissipation between S3 and S5 is ignored, and secondly you have not made it clear up to this point that F3 included averaging over only the part of the fjord width to the east of the island - is that the case? Any dissipation estimate would really be between the locations of your measurements (i.e. S2 and S5) not between S2 and S3 as you claim. Hence you cannot state that 40-70% of the energy flux is dissipated within 7km, but rather over 10km (the distance to S5). I suggest confining your budgeting to the regions bounded by the locations where you actually have measurements.

Diffusivity estimates: To be incorporated into the energy budget, these diffusivity estimates need to be made over the whole basin. At what location are the density profiles used for these estimates? If they are made for a single location for each basin, how can you justify using them in the volume average used in equation 22? Some parts of the basin, e.g. near topography, might have much greater mixing, and very different

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stratification to other locations.

In summary, I find the energy budget calculations, involving flux estimates, dissipation estimates (through divergence of the flux), and mixing efficiency (through diffusivity), to contain several unjustified assumptions. I strongly encourage the authors to be more careful in extrapolating point measurements to basinwide estimates, and to at least give some measure of the uncertainty in doing so, and hence the resultant uncertainty in the dissipation and mixing efficiency estimates.

Technical comments

Abstract, p316 line 4: "tidal current" should be "tidal currents".

Abstract, p316 line 5-6: This sentence (with specific values of amplitude ratios and error estimates) seems very specific for the abstract - I suggest instead focusing on the implications of these numbers for the physical conclusions.

Abstract, p316 line 11: insert "be" before 0.09-0.11.

Abstract, p316 line 13: "only a fraction" - a fraction of what? (I think of the total baroclinic energy lost in the basin) - clarify.

Introduction, p316 line 22: "Without this reduction there would be no renewals of the deep water." - more explanation needed.

Introduction, overall: The introduction reads too much like a list of references with little indication why these references are actually relevant to the current study. I suggest the authors rewrite it completely, focusing on the story of the physics they wish to outline, using the references as supporting evidence for the physical phenomena/understanding to date. Also, the reader would be helped greatly by referring to a map of the region in the introduction, identifying locations such as the Drobak Sill, rather than waiting until section 2.

Section 2.1, p319 line 2: indicate the inner and outer parts of the fjord on the map.

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Section 2.1, p319 line 7: Indicate the Drobak jetty and western inlet on map.

Section 3.1, p323: Please indicate (a) why you describe "displacement at 20m" - aren't you finding the displacement of a density surface? What density? How do you make your choice of density surface?

Section 3.1, p324, line 2: Clarify which location these phase speeds are estimated for.

Section 3.1, p324, line 6: "already found value of Cp" should be "value of Cp already found".

Section 3.1, p324, line 10: "orbital currents" - please explain what you mean by this - do you mean "baroclinic currents"?

Section 3.1, p324, eqn 4: Here is a definition of the "orbital current" - put this earlier, to define "orbital current" when the term is first used. Also, what do you mean by "in the same direction as the internal wave" - do you mean in the same direction as the internal wave PROPAGATION? (i.e. the horizontal direction aligned with the propagation direction?)

Section 3.1, p325, line 15-16: "energy is transferred from the first mode to higher modes" - however, examination of the phase shift in figure 6 does not indicate multiple zero crossings that one might associate with higher modes.

Section 3.2, p326, line 14: "amplitudes of the temperature surfaces" should be "amplitudes of the temperature surface displacements".

Section 3.2, p326, line 24-25: Similarly, "amplitudes of the ....density surface" should be "amplitudes of the ...density surface displacement" and "sea surface amplitude" should be "sea surface elevation amplitude". This correction needs to be made numerous places in the text.

Section 3.2, p327, eqn 7: I have trouble seeing how eqn 7 follows from eqn 6. How does a ratio of amplitudes depend on the phase of the internal wave relative to the sill?

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Also, what do you mean by Y, the surface area of the fjord inside the sill - do you mean the entire surface area of all the basins? How can the amplitude of the internal wave just near the sill depend on the total surface area of the basins, especially when you show that the internal waves are essentially dissipated before they reach basin 5?

Section 4.1, p330, line 1-3: What is the averaging period for the energy density calculations?

Section 4.2, p331, line 6-7: For clarity change "the superscript (p in this case) the method", to "the superscript indicates the method used, in this case p for the pressure method".

Section 4.2, p332: Give details on the A, cross-sectional area, used in these calculations.

Section 4.2, p332, line 24: "the methods based on energy density gives" - should be "give".

Section 5.1, p334, line 23: As far as I can tell (the labels on figure 1 are too small to read, even when the page is blown up to full screen), Aspond Island is between basin 2 and 3, so the energy INTO basin 3, not out of basin 3, goes around this island.

Section 5.2, p336, line 5: Please give details of Y(z), the "hypsographic curve for the basin". How is this different from the topographic depth?

Figure 1: This figure is far too small. I couldn't read much of the text, even when I enlarged the page to full screen. Also, please mark all the locations mentioned in the text, e.g. the inner and outer fjord, the Aspond island, the jetty etc.

Figure 7, caption: "amplitude of density surfaces" should be "amplitude of density surface displacement".

Figure 8: same as for figure 6. Also need "elevation" after "sea level".

Figure 9: Can you show the 99% significance level, or some other way of showing

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which peaks are significant?

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