Review of “Regional modeling of internal-tide dynamics around New Caledonia. Part 2: Tidal incoherence and implications for sea surface height observability”

by Bendinger et al, submitted for publication in Ocean Science

This paper investigates the dynamics and incoherence of the internal tide around New Caledonia using a year-long, high-resolution, realistic numerical simulation at 1/60°.
The present paper is a follow-up to a previously published paper (Bendinger et al. 2023, referred to as “Part 1”) where the authors focused on the coherent internal tide in the same region, mostly based on the same numerical simulation. Here, the authors address three main aspects related to the incoherent tide: 1) the role and nature of the variability of the tidal conversion term (“local incoherence”), 2) the impact of mesoscale variability on the loss of coherence of the internal tide during its propagation (“far-field incoherence”), and 3) the implications of the non-isotropy and incoherence of the internal tide for the definition of a transition length scale between balanced and unbalanced flow. The latter point is related to the use of altimeter data and the issue of disentangling balanced from unbalanced flow, and is timely in the context of the recently launched SWOT mission.

The manuscript is well written, if somewhat long. The methodology is sound and generally well described. The manuscript addresses different issues (two related to IT dynamics and incoherence, one focusing on the implications for SSH imprints), and I think that in some places - which I flag below - the authors could shorten the text. Nevertheless, it is an interesting contribution to the field of physical and observational oceanography, and **I support its publication in Ocean Science**. I do have a few comments, which I call “minor” because they do not compromise the coherence and nature of the results reported.

Comments & questions

Decomposition of the conversion term (eq. 6 and subsequent paragraph)

By construction, when the coherent tide is extracted by least-squares regression, the time average (over the same period as the coherent extraction) of a bilinear product between a coherent field and an incoherent field is expected to be close to zero (minimal in a least-squares sense if the relative magnitude of the different coherent frequencies is similar for the different fields) – see Savage et al. (2020), citing Wunsch (2006).

Section 4.1.

- While the authors only mention the influence of varying stratification as a cause of local changes in the baroclinic bottom pressure and, incidentally, the barotropic conversion term, it should be noted that the direct influence of background currents on generation has also been demonstrated in the literature (Dunphy & Lamb 2018, Shakespeare 2020, Dossman et al. 2020).
- Please specify whether dP_A and dP_ϕ are the amplitude and phase of the incoherent baroclinic bottom pressure $P - P_{\mathrm{coh}}$, or whether it is the difference of the amplitude and phase of the total (coherent + incoherent) and coherent baroclinic bottom pressure. Also, is it possible that the phase term cancels out when averaging over the subdomains?

Section 5 and 2.3

- I am not convinced of the relevance of the results described in this section. I encourage the authors to clarify how this analysis adds to our understanding of internal tidal dynamics and incoherence. What is the added value of the ray tracing approach? No quantitative information is derived from it, the only interpretation it is that the ray paths are more scattered in the south compared to the north, which is sort of expected by nature, given the differences of mesoscale activity. Furthermore, it does not provide any significant additional information compared to the results previously presented in Bendinger et al. (2024). Also, the authors mention that the role of variations in phase velocity (related to stratification) remains unknown, but I think it could be incorporated into their ray tracing approach by using the model stratification instead of a climatology (see e.g. Zaron & Egbert 2014). I agree that several papers have found that background currents have a dominant effect on IT refraction, but not that the latter is negligible - to my understanding. Unless this section is enriched or the relevance of the results emphasised, I would suggest that this section be shortened.
- Please describe the ray tracing experiments in more detail: do you start a ray from each starting point every day to get the different ray paths? How many paths are computed?
- Section 2.3: since this is essentially copied and pasted from Bendinger et al (2024), I suggest shortening this section – possibly keeping the detailed description as an appendix.

Figure 11 in Summary

I am rather sceptical that this figure helps to provide a synthetic view of the results. I think the text is sufficient (and even clearer).

Others, general or specifics

- I do not think that internal tide needs to be hyphenated in the title
- The introduction touches on various aspects of internal incoherence, but does not give much detail on what is known in the region. I understand that the regions have not received much attention until recently (in terms of IT dynamics and incoherence), but it could be seen as a synthesis of what is known. For example, I noticed that New Caledonia can be identified in the incoherent variance fraction estimates of Zaron et al. (2017) or Nelson et al. (2019).

- Eq. 1: Please briefly explain where this equation comes from (and/or add relevant references).
- L. 208–210: There is an incoherence here: depth-independent currents correspond only to a barotropic structure, as a mode-1 baroclinic current as a vanishing vertical integral (or average). My understanding is that using depth-independent currents for the ray-tracing approach is rather a simplification, because including the effect of the vertically sheared background current is complicated – unless one is willing to implement a much more complicated approach, as in Duda et al. 2018 or Guo et al (2023)
- On l.304, the authors claim that local effects associated with local stratification changes are associated with a modulation of the amplitude of the baroclinic bottom pressure, while remote effects are associated with pressure phase variations. Is there any evidence or previous work to support this claim? While I suppose the former can be anticipated from linear theory (e.g. following St Laurent & Garrett 2002), I do not see a straightforward explanation for the impact of remote waves being associated only with phase variations.
- l.325: Again, how are variations in near-bottom stratification and bottom pressure related? Is this straightforward from the above equation for $p(z)$?
- Figure 5 caption: missing parenthesis at end of first sentence.
- l.409: the delay is in hours, not days. Also, the delays obtained are shorter in the south than in the north, which is somewhat contradictory with the fact that IT is more incoherent there.

References (not mentioned in the manuscript)

- [Dossmann et al 2018]: Dossmann, Y., Shakespeare, C., Stewart, K. & Hogg, A. McC. Asymmetric Internal Tide Generation in the Presence of a Steady Flow. Journal of Geophysical Research: Oceans 125, e2020JC016503 (2020).
- [Dunphy & Lamb 2018]: Lamb, K. G. & Dunphy, M. Internal wave generation by tidal flow over a two-dimensional ridge: energy flux asymmetries induced by a steady surface trapped current. Journal of Fluid Mechanics 836, 192–221 (2018).
- [Nelson et al 2019]: Nelson, A. D. et al. Toward Realistic Nonstationarity of Semidiurnal Baroclinic Tides in a Hydrodynamic Model. J. Geophys. Res. Oceans 124, 6632–6642 (2019).
- [St Laurent & Garrett 2002]: St. Laurent, L. & Garrett, C. The Role of Internal Tides in Mixing the Deep Ocean. Journal of Physical Oceanography 32, 2882–2899 (2002).
- [Savage et al 2020]: Savage, A. C., Waterhouse, A. F. & Kelly, S. M. Internal tide nonstationarity and wave-mesoscale interactions in the Tasman Sea. J. Phys. Oceanogr. 1–52 (2020) doi:10.1175/JPO-D-19-0283.1.
- [Shakespeare 2020]: Shakespeare, C. J. Interdependence of internal tide and lee wave generation at abyssal hills: global calculations. J. Phys. Oceanogr. (2020) doi:10.1175/JPO-D-19-0179.1.
- [Wunsch 2006]: Wunsch, C. Discrete Inverse and State Estimation Problems: With Geophysical Fluid Applications. (Cambridge University Press, Cambridge, 2006). doi:10.1017/CBO9780511535949.
- [Zaron & Egbert 2014]: Zaron, E. D. & Egbert, G. D. Time-Variable Refraction of the Internal Tide at the Hawaiian Ridge. Journal of Physical Oceanography 44, 538–557 (2014).