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Ocean Science
Discussions

Interactive comment on "Seiche excitation in a highly stratified fjord of southern Chile: the Reloncaví fjord" *by* Manuel I. Castillo et al.

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General comment this is an interesting paper which describes the internal seiches in a Chilean fjord on the basis of a data set extending over three months. The analysis follows standard procedures, is competently executed and the results are clearly presented. As far as I can see, there are no arresting, novel results but given the sparsity of observations of internal oscillations in fjords, especially in the extensive fjords of the Chile coast, there would seem to be a fair case for publication in Ocean Science. I sense that, be for publication, there are a number of aspects, detailed below, in which the analysis and presentation of the results could be improved and the interpretation enhanced.

1) My main concern about the paper is that it does not clearly identify the relative im-

portance of the seiche in the overall dynamics and mixing processes in the fjord. There is a strong barotropic tidal forcing which, ïňĆowing over the sills, will tend to induce a small (?) M2 internal tide. As the authors indicate, there is also an energetic Estuarine Circulation in response to the considerable freshwater input to the fjord as well as wind-driven motions, notably at the diurnal frequency. In this situation it would be good to know the contribution of the internal seiches in relation to the other components of ïňĆow. This might be done by including a plots over time of the kinetic energy in each component (as in ïňĄg 7 but for all components).

Answer The paper was focused on the seiche presence because the subtidal dynamics has been studied by the authors in others works (Castillo et al., 2012, 2016). The estuarine circulation is the main characteristic of the upper circulation (layer between 0 to 30 m) within the fjord. The deep circulation presents the influence of tides on the variability in contrast to the upper layer where the tide represents less than 20% of the variability. Despite the fact that in the first part of the study we shows the total variability of the time series, the scope of the study is center on the 3 day band the limits which were obtained from the two approximations a) the reduced gravity (RGM), and b) continuously stratified (CSM) models.

We will incorporate the contribution in terms of kinetic energy for the total, the tidal, and the 3 days band in order to compare the different parts of the flow, but as we indicate the main variability will be associated to the estuarine flow in the upper layer. Here, the study wants to shows that the internal oscillation of the basin must be include on the estimations of mixing.

Finally, according with the reviewer suggestion we include on the new figure 7, the relative contribution to the kinetic energy of the terms indicated above.

2) The log-log plots of spectral energy density are not suitable for comparison of the relative variance contribution and could, with advantage, be replaced by "equal variance plots" in which you plot P(f) x f versus log f which do demonstrate the relative

magnitude of the energy in different peaks.

Answer Thanks for your help, and as you indicated the equally variance plots helps to identify the main peaks of energy, but less energetic peaks, but notorious, vanishing with this technique (see Figure included).

We think that the log-log spectrum provide us a detailed description of the different kind of oscillations present on the time-series, we are aware about the fact that there are some of those oscillations more energetic than others but even that, the less energetic oscillation like the 1.3h peak in the sealevel is extremely consistent with the presence of a barotropic seiche in the fjord which is not possible to observe using the equal variance spectrum.

3) Differences in the spectral peaks at âĹij12h (ïňĄg 4) suggest that there is a signiïňĄcant internal tidal response as has been observed in other fjords (e.g.Allen and Simpson, Winant 2010). You could isolate this component either by projecting on to the modes or by cross-spectral analysis of ïňĆow in the upper and lower layers.

Answer Thanks for the suggestion, in fact the internal tides dynamics is the main topic of the ongoing manuscript from the same authors which take results not only from the Reloncavi fjord also to another fjord of the southern Patagonia. We think that the tidal variability is a different topic and out of the scopes of the manuscript. In the case of the internal tides, recently on the southern Patagonian fjords Ross et al (2014, 2015) showed the relatively importance of the internal tides in the high frequency dynamic of the fjords, indeed in the manuscripts they shows to different ways of forcing for the internal waves: GLOFS and low-frequency changes of barometric pressure. As part of a new project, the group involves in this manuscript is worried about the forcing for one hand tides inducing internal tides due to the pycnocline interaction with the bathymetry for example, and for other hand winds could perturb the pycnocline inducing natural oscillations of the basin. We wants to maintain the manuscript scope on the 3 days oscillation which clearly is due to the natural internal oscillation of the Reloncavi fjord,

this finding is extremely relevant for the region because is the first time that the process it is described for the southern Patagonian fjords.

References:

Ross, L., Pérez-Santos, I., Valle-Levinson, A., and Schneider, W. 2014. Semidiurnal internal tides in a Patagonian fjord. Progress in Oceanography, 129: 19-34.

Ross, L., Valle-Levinson, A., Pérez-Santos, I., Tapia, F. J., and Schneider, W. 2015. Baroclinic annular variability of internal motions in a Patagonian fjord. Journal of Geophysical Research: Oceans, 120: 5668-5685.

4) The paper emphasizes the consistency of the density structure but it does vary somewhat (âĹij20%) and it would be useful to relate this variation to the changes in stratiïňĄcation due to variations in freshwater input and surface heating/cooling. Presumably salinity is the main control on density but surface heat exchange may also be playing a role?

Answer We think that the surface heat exchange may play a role in the upper column, in fact on the brackish water layer, were temperature could be more important to the density instead of salinity. We consider include a description of the relevance of the heating/cooling of the upper layer which has a marked seasonal cycle. You must notice that rivers on the region are colder in winter producing a clear thermal inversion (Castillo et al., 2016) while in summer the surface waters could reach until 18°C probably by heat gained by the solar radiation. But the development of the pycnocline along the seasons is consistent with the freshwater input suggesting that the variability of the density in the upper layer is dominated by the freshwater input instead of the surface heating/cooling.

Reference:

Castillo, M.I., Cifuentes, U., Pizarro, O., Djurfeldt, L., Caceres, M., 2016. Seasonal hydrography and surface outflow in a fjord with a deep sill: the Reloncaví fjord, Chile.

Ocean Sci. 12, 533-544.

5) I was surprised that there is not more evidence of the external seiche which was clearly represented in Gullmar fjord of (Arneborg and Liljebladh 2001) Presumably it is apparent in your results as a weak peak in the sea level spectra which scarcely shows in the velocity data. Is this because your noise level is rather high due to your long sampling interval of 20 minutes which doesn't allow averaging if you want to detect a 78 minute seiche?

Answer As the reviewer indicated, the interval time is too long to properly evaluate the 1.3h barotropic seiche in the fjord but that oscillation was mainly observed on the sealevel spectra because on those instruments the interval was 10 minutes instead of the 20 minutes interval used on currents. In the fjord region of Chile the study of that dynamics has been scarcely studied and the main objective of the study was the 3 days band. Despite that we think that the lo-log spectrum of the sealevel it is a good way to observe insights of the internal seiche thus we decide to maintain the representation of the spectrum in loglog plots.

6) The paper is generally well written but the English, which is not always clear and idiomatic, needs some attention.

Answer After make all the corrections indicated by the reviewers, we will send the manuscript to a native English spoken or we will use the American Journal Experts services (www.aje.com) to check the language of the manuscript.

References Winant C.D. (2010): Two-Layer Tidal Circulation in a Frictional, Rotating Basin, JPO 40(6), 1390-1404. Allen, G., and J. Simpson, 1998: ReïňĆection of the internal tide in Upper Loch Linnhe, a Scottish fjord. Estuarine Coastal Shelf Sci., 46, 683–701.

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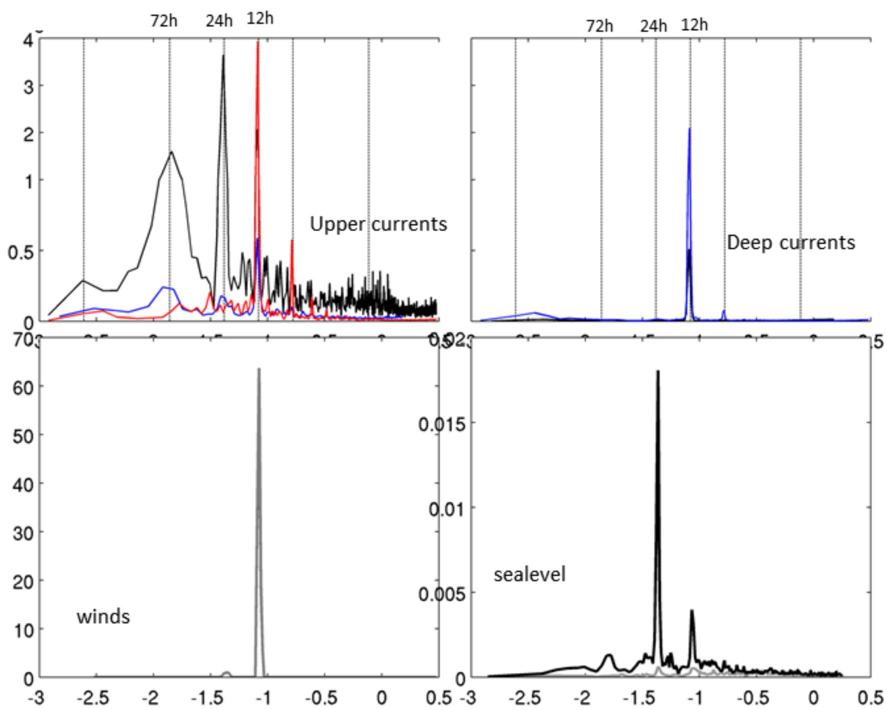

Fig. 1. equally variance spectrums of currents, winds and sealevel