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Interactive comment on "Surface seiches in Flathead Lake" *by* G. Kirillin et al.

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The manuscript describes a novel method to extract the spatial seiche modes in Flat-head Lake including rotary spectra that will be useful for other sites.

We thank the Reviewer for mentioning specifically the novelty and the effectiveness of the proposed methodology, which, we believe, is one of the two major advances of the study, among with the morphometry-related mechanisms of seiche generations.

The seiche frequencies are retrieved from a numerical model that is given an initial disturbance. Next the output at one location at the middle of the lake is used to find the significant peaks in the spectrum. These individual harmonics are then analyzed at all model grid point locations to get the spatial and temporal distribution. Based on the comparing of the full time series with the

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reconstructed harmonic time series at this single location the au-thors assume that by the total variance at all locations within the lake is conserved. Given the nodal structure of the modes this is not necessarily true and should be verified. It would be worthwhile to check the spatial distribution of the total variance explained by the 16 harmonics to see whether this is correct.

We did not used one location at the middle of the lake for determining the spectrum peaks, it would be trivial and ineffective. A spectrum was taken of the free surface oscillations at every *grid point of the model domain. Then, a "maximum spectrum estimation" was constructed by superimposing the significant spectral peaks among all grid points. The significance level of the spectral peaks was defined as the upper 99% significance level for red noise signal containing the same variance as the spectrum estimation. This approach conserved the "local modes" with relatively high amplitudes but confined to small areas, like bays or straits.*

We thank the Reviewer for providing us the opportunity to improve the method description. We added the following text to the paper to make the method description more precise:

Harmonic analysis relies on a prescribed set of frequencies persisting in the analyzed signal. Therefore, it became to a state-of-the-art method in the analysis of tidal motions, where the prevailing frequencies are determined by the external forcing and are fixed independently from the characteristics of the water body. Harmonic analysis is rarely, if ever, applied to the seiches, as their harmonics cannot be known a priori*. Being defined by the basin morphometry, the contribution of different harmonics into the total variance of surface oscillations varies spatially over the lake. Therefore, neither single point data nor the spectrum averaged over the lake area are representative for the entire basin. In order to uncover the frequencies set of seiche oscillations relevant to the whole lake, the following procedure was developed and applied. In order to retain only the oscillatory motions in the surface elevation time series, the mean values were removed from velocity and surface elevation records. A spectrum was taken of the*

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free surface oscillations at every grid point of the model domain. Then, a "maximum spectrum estimation" was constructed by superimposing the significant spectral peaks among all grid points. The significance level of the spectral peaks was defined as the upper 99% significance level for red noise signal containing the same variance as the spectrum estimation (Kirillin 2008). This approach conserved the "local modes" with relatively high amplitudes but confined to small areas, like bays or straits.

The fact that the present method does not give an idea of the absolute value of the seiche surface elevation and velocity it seems a leap to state the importance of the seiche modes in sediment transport, coastal erosion and transport of biota. You need a quantitative assessment for that. Based on the measurements presented in Figure 10 the variation in the water elevation at the various stations is quite limited. Furthermore, it seems that the time scales of many of these oscillations are significantly longer than any of the modes discussed in the paper, i.e. more on the order of days than hours. To have a better idea of the seiche contribution to the changes in water elevation it would make sense to use the same harmonic decomposition of the measured time series, i.e. include the 16 harmonics only. That would allow for a quantitative evaluation of the seiche impacts and a connection to the coastal impacts. At present that is not the case and the conclusions in the manuscript are too strong.

The comments on the potential impact of seiches on overwash are interesting, but again it should be seen in connection with the wind- and wave induced set-up at that time. It is not a simple linear super position of the various contributions to get to over-wash.

Application of the harmonic analysis (i.e. decomposition of the times series using the set of prescribed frequencies) is normally not effective for seiches data. In contrast to tidal variations, the seiche signal, as also demonstrated by the present study, is unevenly distributed over the lake surface, with different frequencies prevailing at different *locations. The seiche-driven pressure oscillations are also weaker than the tidal ones and are masked by wind waves and long-term water level variations. Spectral analysis of the measured time series, as presented in Fig. 9 of our paper, is much more effective, especially, when the spectral peaks revealed by the spectral analysis can be directly identified by comparison against modeling results, as it is in our case.*

- the large-period oscillations in the measured time series (Fig. 10) result from the lake level regulation by Kerr Dam operation. The dam regulates the level variations to keep the maximum water level below the prescribed maximum of 881.78 m a.s.l, minimizing their potential effect on overwash and/or shoreline erosion. Seiche oscillations, in turn, are missed by the regulation procedure, and, as we demonstrated, repeatedly exceed the prescribed maximum water level. Therefore, we included into Discussion the potential role played by seiches in coastal erosion, sediment transport and overwash, placing our results in a general context of the lake hydrodynamics.

- In response to the Reviewer's remark we have edited Fig. 9 and extended the spectral analysis of the observed level fluctuations as follows:

Several important discrepancies between the modeled and observed spectra provide an insight into the features not captured by the model, but potentially significant for the hydrodynamics of Flathead Lake. The high frequency modes with periods of 10-15 min are generally stronger in the observations that in the model. Observations at measurement sites WB and NR (Fig. **??***C, D) show strong oscillations at periods about 10 min, which are not pronounced on the modeled single point spectra from the closest grid points. However, these periods are found in the results of the harmonic analysis: three local modes have periods of 9.96, 10.38, and 11.76 min; among them the 10.38-min mode is predicted to produce appreciable water level amplitudes in the vicinity of the measurement sites WB and NR (see Fig. S1 in* Supplementary Material I*). The likely reasons for amplification of these modes are local interactions between wind and lake topography, which cannot be reproduced in the model driven by the linear initial surface slope.*

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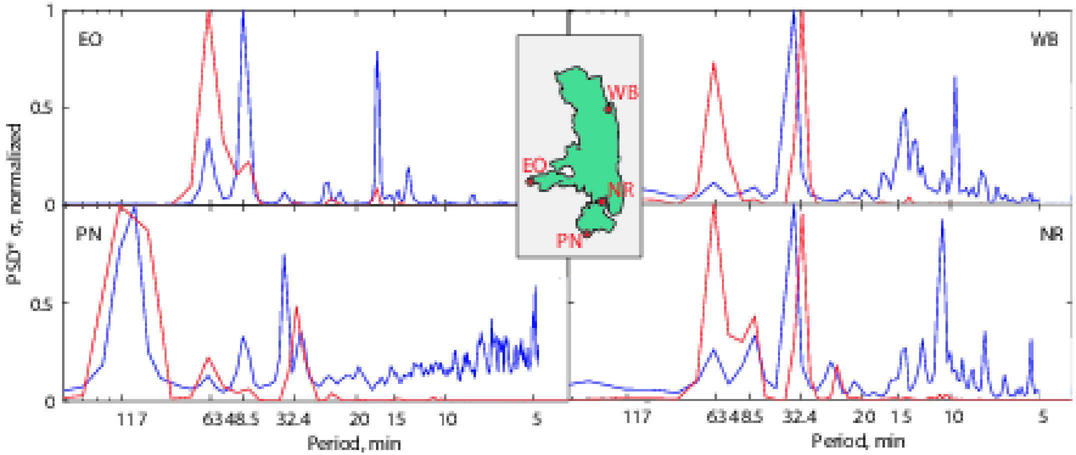

Fig. 1. Spectra of measured (blue) vs modeled (red) free surface oscillations at four different locations in Flathead Lake. The inlet shows the positions of the corresponding measurement points.