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Surface seiches in Flathead Lake, Montana

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Flathead Lake— the largest freshwater lake in the western USA—undergoes significant short-term water level oscillations due to standing barotropic waves (seiches). Large surface area and several embayments cause high amplitudes and complicated spatial pattern of the seiches. We used water level records from 12 sites distributed around the lake and the results of numerical circulation modeling to establish the modal composition of seiches, the two-dimensional wave shape, and current patterns. For this, we directly applied harmonic analysis to the output of a full circulation model. Compared to the traditional reduced eigenvalue problem, the proposed approach allows modal separation of real datasets that is potentially advantageous for analysis of the resonant response to periodic wind forcing. Surprisingly, both model results and observations demonstrated predominance of the 'two-node' horizontal mode, whereas the usually most acute 'one-node' mode was attenuated by the large shallow bay connected through a narrow straight to the main lake basin. Energy of several higher modes was concentrated around the mouth of the main inflow suggesting their strong effect on the redistribution of the inflow waters and suspended matter within the lake. The rotary spectral analysis revealed rotational character of two particular modes and localized potential upwelling/downwelling areas, where water-sediment matter transport could be intensified by 'seiche pumping'. The results have a wide range of applications including transport of dissolved and suspended matter, assement of shoreline erosion, and exchange processes at the water-sediment boundary. In addition, knowledge of the spatial seiche pattern facilitates estimation of the hypothetical lake response to earthquakes in this seismically active region.