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Linear and nonlinear internal waves in a sub-alpine lake

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We characterize and model linear and nonlinear internal wave climate in a long narrow sub-alpine lake: Lake Bourget in France. Field measurements using thermistor chains at different points and comparison with linear models show that the most energetic internal wave motion is a standing internal seiche motion with one node on the vertical and one node on the horizontal dimension (V1H1 mode). Strong evidence of a rotating vertical mode2 Kelvin wave is also found from coherence spectra between isotherm time series at different points. In spring wind forcing is usually strong, and the stratification is relatively weak with a thin epilimnion. As a consequence, the Wedderburn number defined as the ratio of the epilimnion thickness to the metalimnion maximum tilting shows weak values. For such low values of the Wedderburn number, nonlinear effects can no more be neglected and the V1H1 internal seiche evolves as a progressive surge. Under the influence of non-hydrostatics effects, a train of high frequency nonlinear waves is then generated. We model the degeneration of the standing internal seiche into an internal surge and high frequency nonlinear waves using the weakly non linear, weakly dispersive Korteweg de Vries equation. Comparisons of isotherm series as derived from measurements and from modelling show good agreements. These high frequency nonlinear waves are believed to generate high dissipation rate and high turbulent dispersion when shoaling at the lake boundaries and may therefore provide a path-way for nutrients between hypolimnion and epilimnion, forcing by the way some of the important ecological processes in the lake.