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A semi-analytical model for tsunami waves amplification in idealized harbors

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Small tsunamis usually are not a danger for people along the coast, but can cause sizeable losses when they hit harbours where their waves can be amplified. An example of such local amplification is given by the 17 November 2015 tsunami associated with the Mw = 6.5 earthquake in Lefkada, Greece. It was almost unseen everywhere with the exception of the port of Crotone, Italy, where it produced a significant signal, clearly visible in a tide-gauge record. Though tsunami amplification in harbours is a classical textbook problem investigated theoretically and numerically in the literature, we believe that still some theoretical aspects can be better clarified. We propose a semi-analytical model for harbour amplification of the Helmholtz mode. We start with the idealized case of a constant-depth rectangular basin forced by a train of regular normally-incident waves incoming from a flat ocean.

The work was divided into three phases. First, chosen a harbour of given length d (direction normal to the ocean shoreline) and given width w (direction parallel to the shoreline), we build the amplification curve (in term of the dimensionless wavelength $k_d=2\pi d/\lambda$) for the Helmholtz peak. The curve is computed for a set of different basins by varying d and w. It is found that curves depend basically on the aspect ratio w/d. All the calculations of this phase are performed numerically by means of the tsunami linear version of the numerical code UBO-TSUFD.

Second, we interpret the curves by means of a three-parameter theoretical model describing the wave dynamics inside the harbour. The parameters are the wave transmission and reflection coefficients at the harbor mouth and a phase delay. The model is calibrated against the computed amplification curves, and enables the analytical calculation of the Helmholtz mode amplification for rectangular basins of arbitrary aspect ratio.

The third phase consists in extending the model to cover the case of harbours protected by breakwaters As expected the Helmholtz resonance peak increases when the breakwater length increases and the harbor mouth is made narrower.