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Full frequency dispersive numerical modelling of tsunamis. Large scale application to the South Tyrrhenian sea

The model equations

A model based on the MSE (Mild Slope Equation) able of reproducing the full frequency-dispersion of small amplitude tsunamis is presented.

The model uses the Fourier Transform to convert the time dependent hyperbolic MSE (1) into a set of elliptic equations in the frequency domain. The problem therefore reduces to the solution of the elliptic MSE (2) for each frequency component of the wave field.

$$\frac{\partial^2 \phi}{\partial t^2} - \nabla_h \left(c c_g \nabla_h \phi \right) + \left(\omega^2 - k^2 c c_g \right) \phi = 0 \quad (1)$$

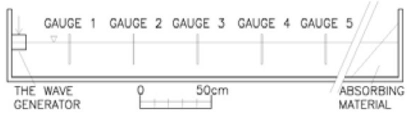
$$\nabla_h \left(c c_g \nabla_h \Phi \right) + k^2 c c_g \Phi = 0 \quad (2)$$

where $\Phi(\omega,x,y)$ is the Fourier Transform of the velocity potential at z=0 $\phi(t,x,y)$.

The time series of the surface elevation is then recovered by means of the Inverse Fourier Transform, due to the linearity of the model.

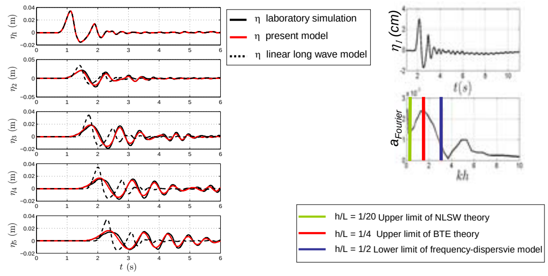
The validation of the model

Results of an available experimental study on generation of impact waves (Scott-Russel waves generator) are used to validate the model.



The experiments have been carried out at the Environmental and Maritime Hydraulic Laboratory (LIAM) of the University of L'Aquila, Italy.

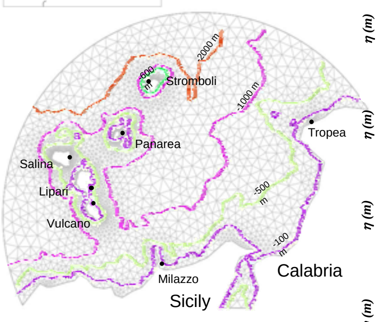
In the model the waves are generated at one boundary by means of an inverse technique.



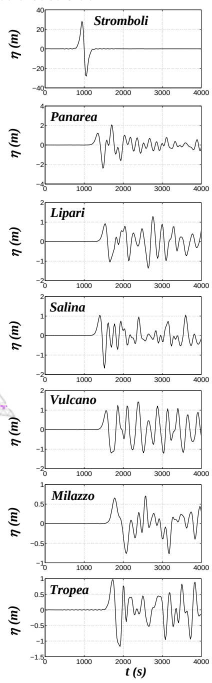
A large scale application

We reproduce the propagation in the South Tyrrhenian Sea of landslide generated tsunami at Stromboli.

The numerical results presented in the figures were picked up at some representative points located at a water depth of approximately -100 m.

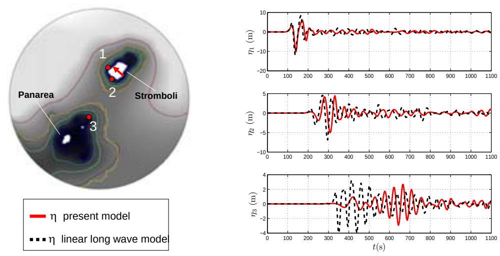


Computational domain with bathymetric contours and the numerical grid (the grid here represented is coarser than that used in the simulations)



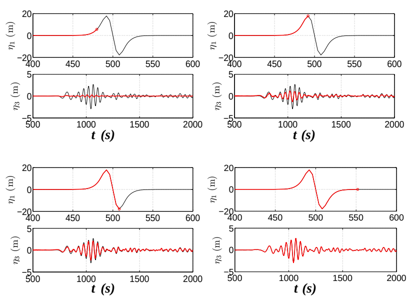
Use of the model in a TEWS

First we compare the present full frequency-dispersive model with a similar model based on the linear long waves theory, to show the importance of the frequency-dispersion.

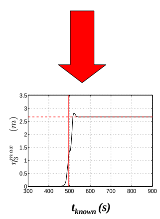


Then we show that the model is very robust and can be used as a support to a **tsunami early warning system**, since it can work also with truncated input time series, as those measured by tidal gauges in the real life during a tsunami attack.

In the figures below it is shown how the model predicts the surface elevation at the point 3, close to Panarea island, as the data become available at point 1, close to the generation area. The upper panels report the measured time series at four consequent instants (red line) at point 1. On the lower panels it is shown the predicted water surface elevation at point 3 calculated using the truncated input time series.



The model adjusts the prediction as the tsunami is detected.



Conclusions

- The numerical model is suitable for the simulation of small-amplitude frequency-dispersive transient waves.
- Tsunamis generated by landslides are properly reproduced by means of a frequency-dispersive model.
- The model is very robust and quick to apply at the operational stage of a tsunamis early warning system.
- The model is not able to reproduce the nonlinear effects.

REFERENCES:

Bellotti, Cecioni, De Girolamo, 2007. Simulation of frequency-dispersive transient waves by means of the mild-slope equation. In Press at *Coastal Engineering*.