Specification of Initial Condition in Numerical Simulation of Seismotectonic Tsunamis

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Numerical simulation of tsunami is normally based on the shallow water theory. As for the description of tsunami generation, an earthquake is considered to instantly cause residual deformations of the ocean bottom. Then, the assumption is made that the displacement of the bottom is simultaneously accompanied by formation at the surface of the ocean of a perturbation (initial elevation), the shape of which is fully similar to the vertical residual deformations of the bottom. The initial elevation, thus obtained, is then applied as the initial condition in resolving the problem of tsunami propagation. A logical development of the traditional approach is to calculate the initial elevation from the solution of the 3D problem taking into account all three components of the bottom deformation vector and the distribution of depths in the vicinity of the source. The suggested method of calculation of the initial elevation in tsunami source does not violate the traditional scheme of tsunami simulation but just optimize it. The first point of optimization consists in the removal from tsunami spectrum of the shortwave components which are not peculiar to real tsunami waves The second point of optimization consists in taking into account not only vertical bottom deformation but all three components of the deformation vector and bathymetry in source area. The Central Kuril Islands tsunamis on November 15, 2006 and on January 13, 2007 are taken as examples to demonstrate the efficiency of the new method.

Dynamic problem

$$\tau << \sqrt{H/g}$$

$$\Phi = \int_0^\tau F\,dt$$

$$\Delta F = 0$$

$$\frac{\partial F}{\partial \vec{n}} = \left(\frac{\partial \vec{\eta}}{\partial t}, \vec{n}\right), \quad z = -H(x,y)$$

$$\frac{\partial^2 F}{\partial t^2} = -g\frac{\partial F}{\partial z}, \quad z = 0$$

$$\xi(x,y,t) = -\frac{1}{g}\left.\frac{\partial F}{\partial t}\right|_{z=0}$$

$$\vec{v}(x,y,z,t) = \vec{\nabla} F$$

Static problem

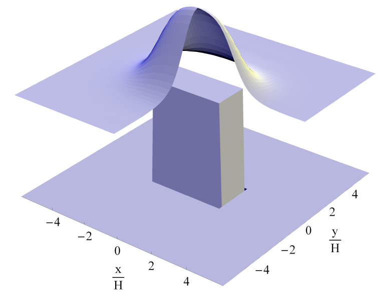
$$\Delta \Phi = 0$$

$$\Phi = 0, \quad z = 0$$

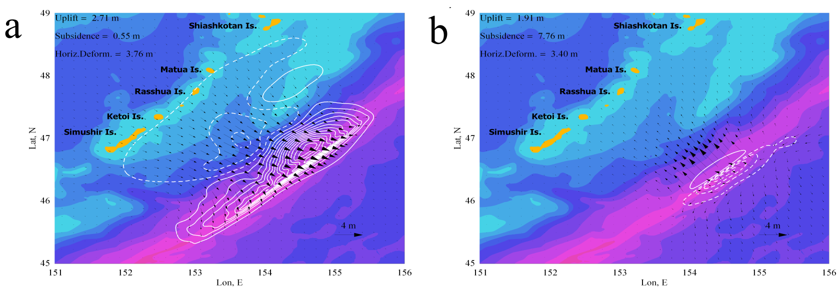
$$\frac{\partial \Phi}{\partial \vec{n}} = \left(\vec{\eta}_0, \vec{n}\right), \quad z = -H(x,y)$$

$$\xi_0 = \left.\frac{\partial \Phi}{\partial z}\right|_{z=0}$$

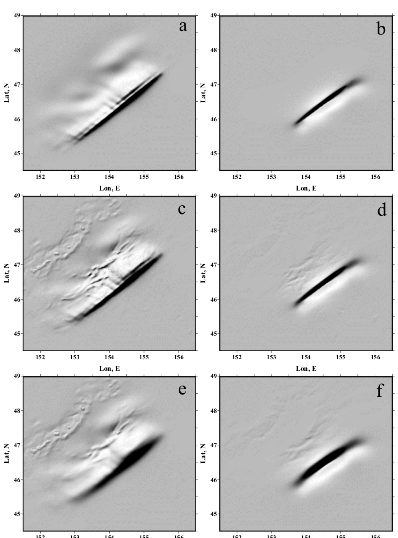
F – velocity potential, H – depth, η – vector of bottom deformation, ξ_0 – initial elevation



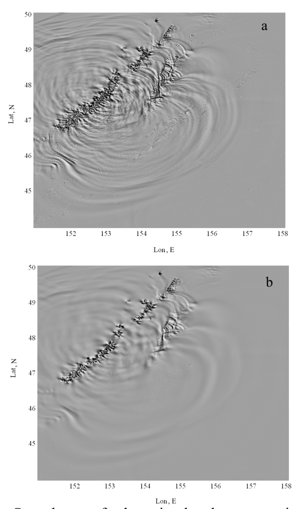
Free surface disturbance caused by residual bottom deformation of rectangular shape (potential theory, analytical solution). Surface disturbance and bottom deformation are shown in the same scale. Displacement of the free surface is much smoother as compared with the bottom deformations: initial elevation has smaller amplitude and spreads over a rather wide area.



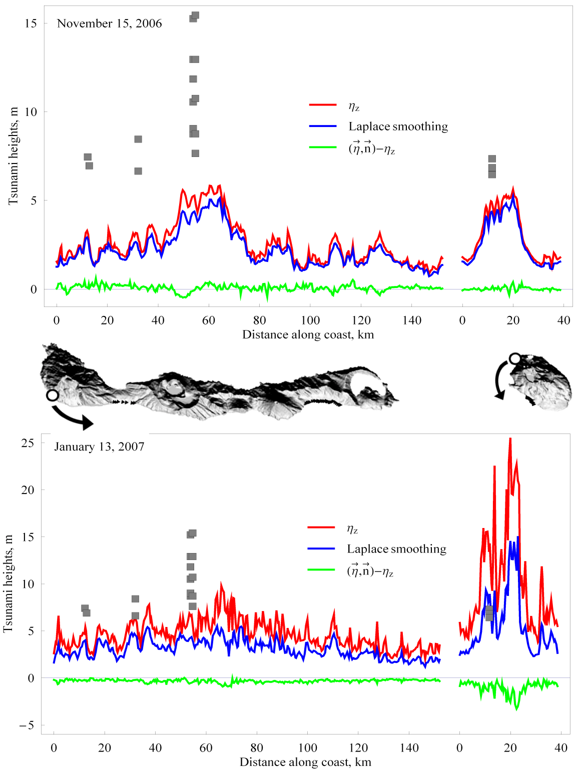
Bottom topography and vector fields of residual bottom deformation for the tsunamigenic Central Kuril Islands earthquakes of November 15, 2006 (a) and of January 13, 2007 (b). The isobaths are drawn with an interval of 1 km. Vertical bottom deformation is shown by isolines drawn in steps of 0.2 m (a) and 1 m (b). Black arrows stand for horizontal bottom deformation; scale arrow (4 m) is depicted in the right down corner.



Initial elevation of water surface in tsunami sources of November 15, 2006 (left column) and of January 13, 2007 (right column). *a, b* – vertical bottom deformation: η_{0z} ; *c, d* – contributions of vertical and horizontal bottom deformation: $(\vec{n},\vec{\eta}) \equiv n_x\eta_x + n_y\eta_y + n_z\eta_z$; e, f – the Laplace smoothing algorithm: $\xi_0(x,y)$.



Snapshots of the simulated propagation of January 13, 2007 tsunami at time moment 3000 s after the earthquake. The initial elevation assumed to be equal to the vertical bottom deformation (a); calculated with use of the Laplace smoothing algorithm (b).



Synthetic (curves) and in-situ measured (gray squares) run-up heights along the coasts of Simushir and Ketoi Islands. Red curves stand for the traditional method of specification of the initial elevation; blue curves – the Laplace smoothing method. Green curves denote difference in run-up heights of tsunamis originated from the initial elevation calculated with account of horizontal and vertical components of bottom deformation and with account of the vertical component only. Relief maps of the islands; starting points (white circles), where the distance along the coast is equal to zero, and the direction of "traveling" along the coasts (black arrows).

Publications:

Nosov M. A., Kolesov S. V. *Optimal initial conditions for simulation of seismotectonic tsunamis,* Pure and Appl Geophys (In print)

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