Tsunami Observer: automatic system for estimate of tsunamigenicity of an earthquake

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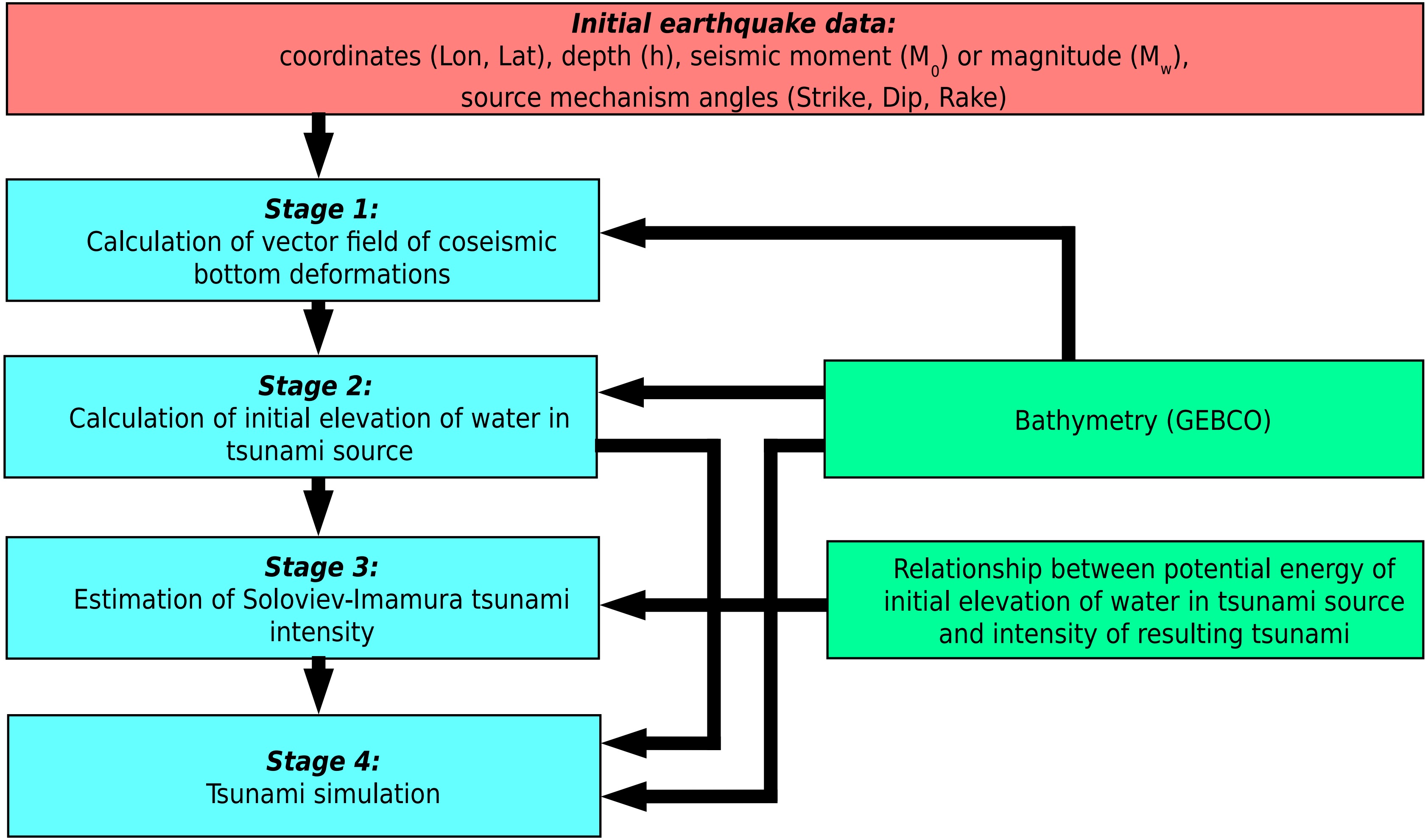
Tsunami Observer principles

The input dataset for the system includes earthquake coordinates, earthquake depth, seismic moment, focal mechanism. We use datasets provided by USGS and GEOFON. Upon receiving earthquake data the system performs the following consecutive actions. At first, the vector field of co-seismic bottom deformation is obtained using earthquake fault parameters and empirical relationships. Then the initial elevation in tsunami source is calculated and estimation of Soloviev-Imamura tsunami intensity is performed. Initial elevation is calculated taking into account vertical and horizontal components of bottom deformation, local bathymetry (GEBCO) and smoothing effect of water layer.

“Tsunami Observer” flowchart



Focal mechanism sources

- USGS significant earthquakes RSS feed
- GEOFON moment tensor solutions catalogue

Only M_w6+ events are processed

Fault plane parameters estimation

$$W = C_1 L^{2/3}$$

$$D = C_2 \sqrt{LW}$$

$$C_1 = 17.5\ (12 \div 25)\ m^{1/3}$$

$$C_2 = 3.8\ (1.5 \div 12) \cdot 10^{-5}$$

$$\mu = 3.3 \cdot 10^{10}\ Pa$$

Using relations from:

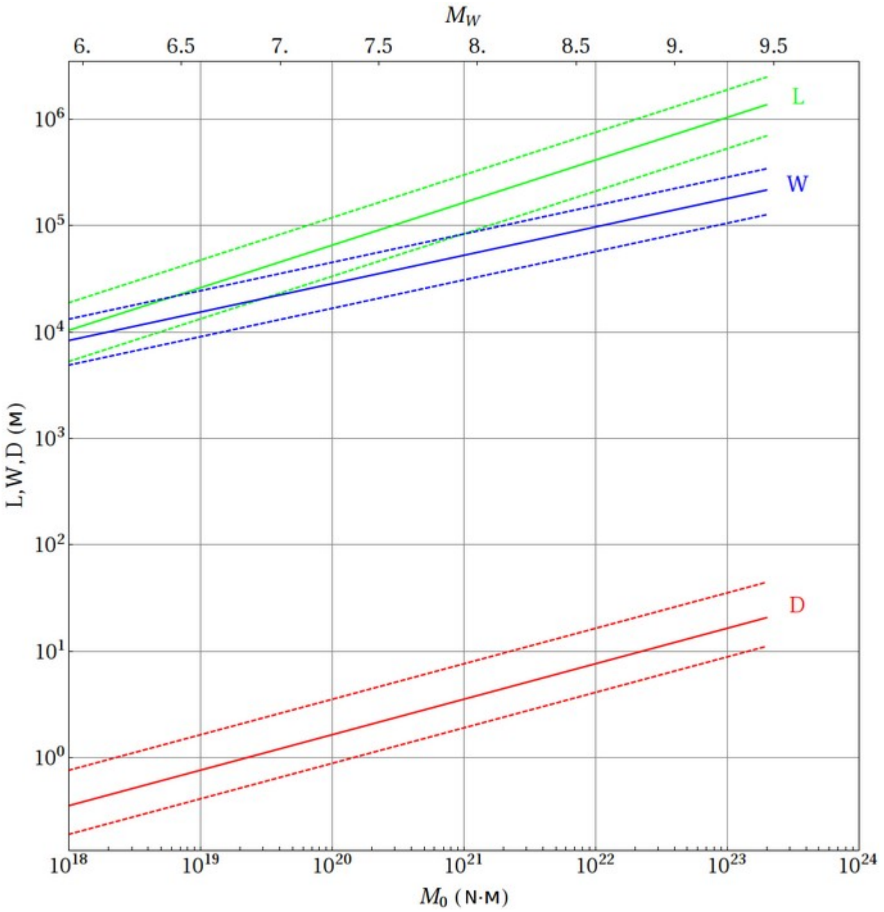
Leonard M. Earthquake Fault Scaling: Self-Consistent Relating of Rupture Length, Width, Average Displacement, and Moment Release //Bulletin of the Seismological Society of America, Vol.100, No.5A, pp.1971–1988, October 2010, doi: 10.1785/0120090189

$$M_0 = \mu D L W$$

$$\log L[m] = 2/5 \log M_0 - 3/5 \log C_1 - 2/5 \log C_2 \mu$$

$$\log W[m] = 4/15 \log M_0 + 3/5 \log C_1 - 4/15 \log C_2 \mu$$

$$\log D[m] = 1/3 \log M_0 + 2/3 \log C_2 - 1/3 \log \mu$$



Calculation of vector field of coseismic bottom deformations

We use **ffaultdisp** utility – our implementation of Okada formulae

http://ocean.phys.msu.ru/projects/ffaultdisp/

Smoothing of initial elevation of water in tsunami source

Bottom deformation: $\eta = D_x \frac{\partial H}{\partial x} + D_y \frac{\partial H}{\partial y} + D_z$, where $\vec{D}$ is the vector of deformation

Initial elevation: $\xi_0(\vec{r}_j) = \frac{\sum_i f(|\vec{r}_i - \vec{r}_j|)\eta(\vec{r}_i)}{\sum_i f(|\vec{r}_i - \vec{r}_j|)}$

Weight function: $f(|\vec{r}_i - \vec{r}_j|) = \frac{1}{\cosh^2(|\vec{r}_i - \vec{r}_j| / H(\vec{r}_i))}$

Variable window size: $6H \times 6H$

Kuril Is.
M_w7.5
25 Mar 2020

Focal mechanism data appeared in:

Geofon: 88 min
USGS: 20 min

Estimated tsunami intensity:

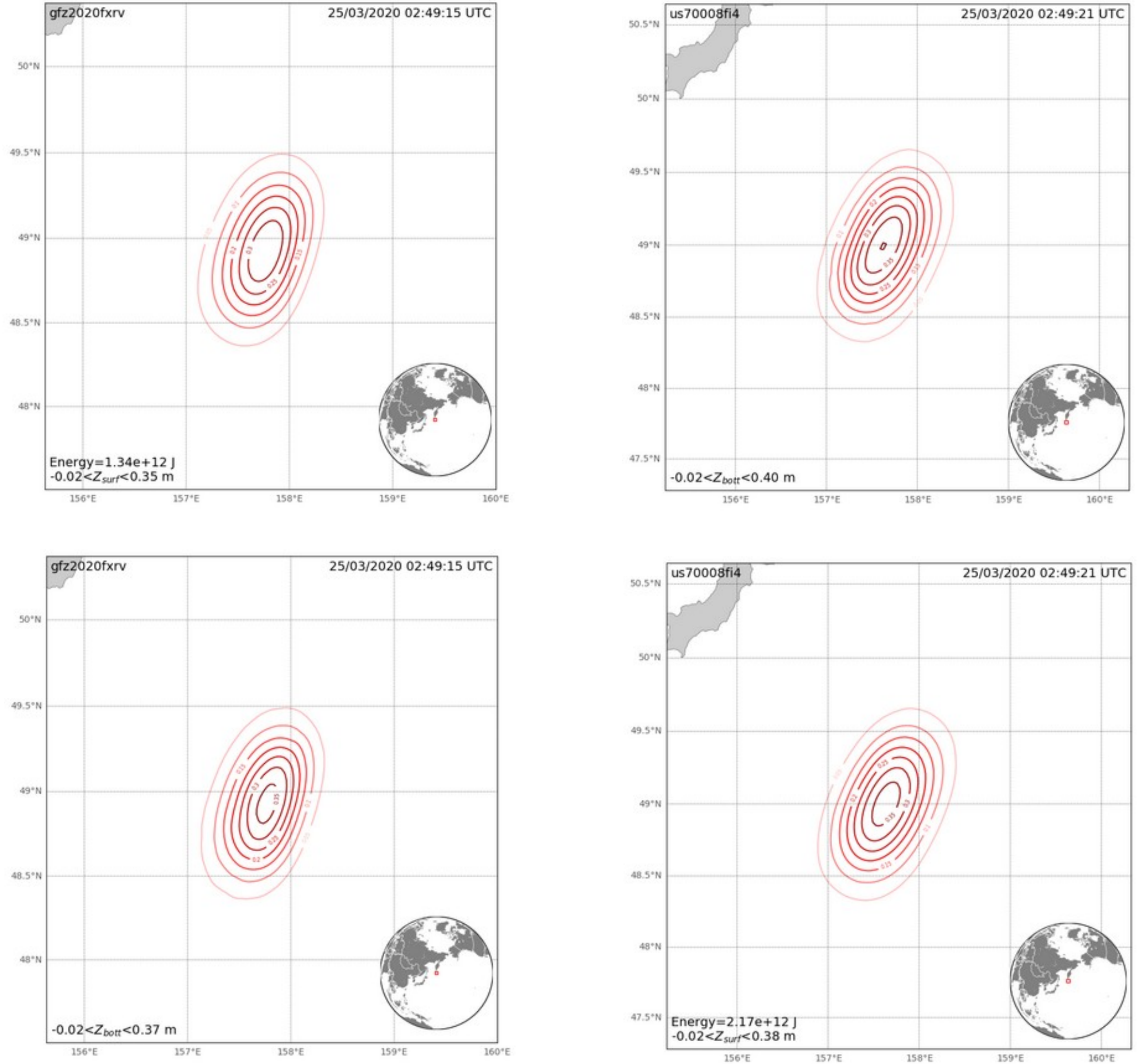
according Geofon data: -0.9±1.6
according USGS data: -0.7±1.6

Max water height by NCEI: 0.50 m

According GEOFON | According USGS

Coseismic bottom deformation

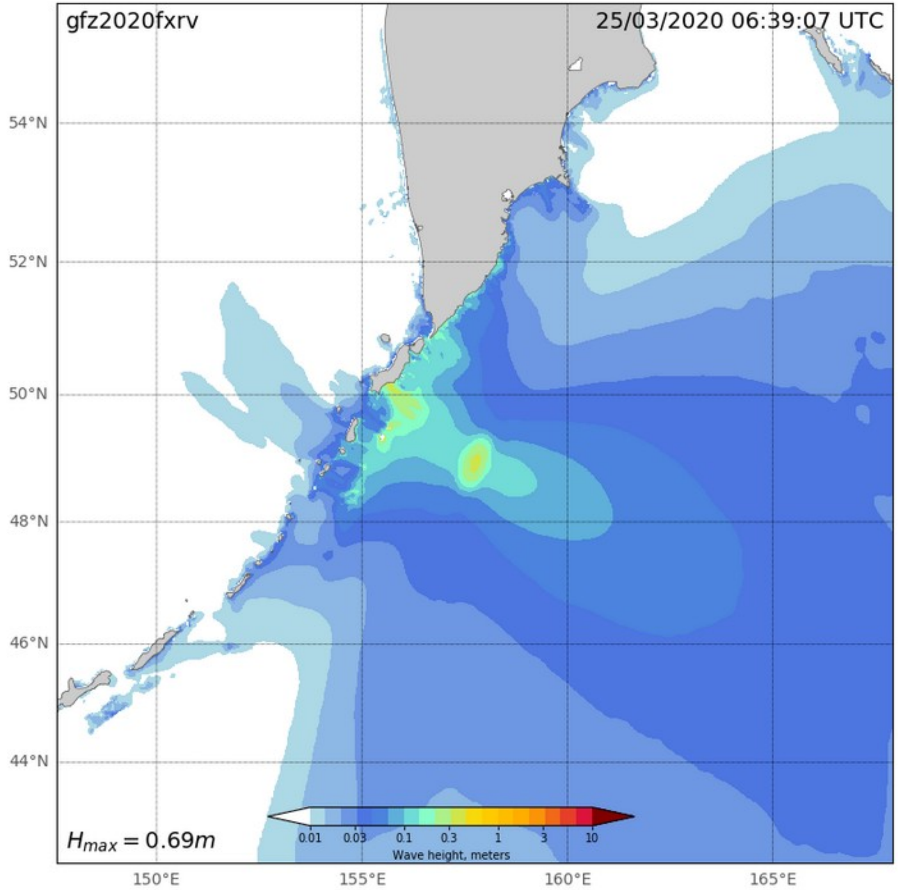
Elevation of water surface



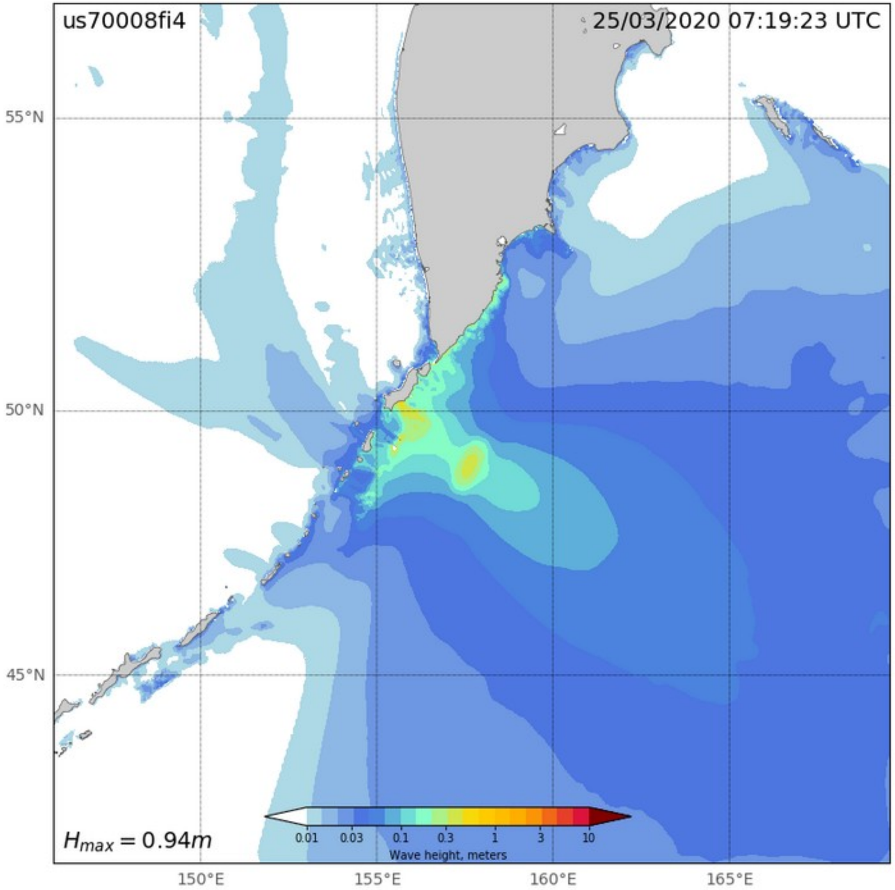
Kuril Is. M_w7.5 25 Mar 2020

Max water height

According GEOFON



According USGS



Crete
M_w6.6
2 May 2020

Focal mechanism data appeared in:

Geofon: 23 min
USGS: 20 min

Estimated tsunami intensity:

according Geofon data: -1.7±1.5
according USGS data: -1.7±1.5

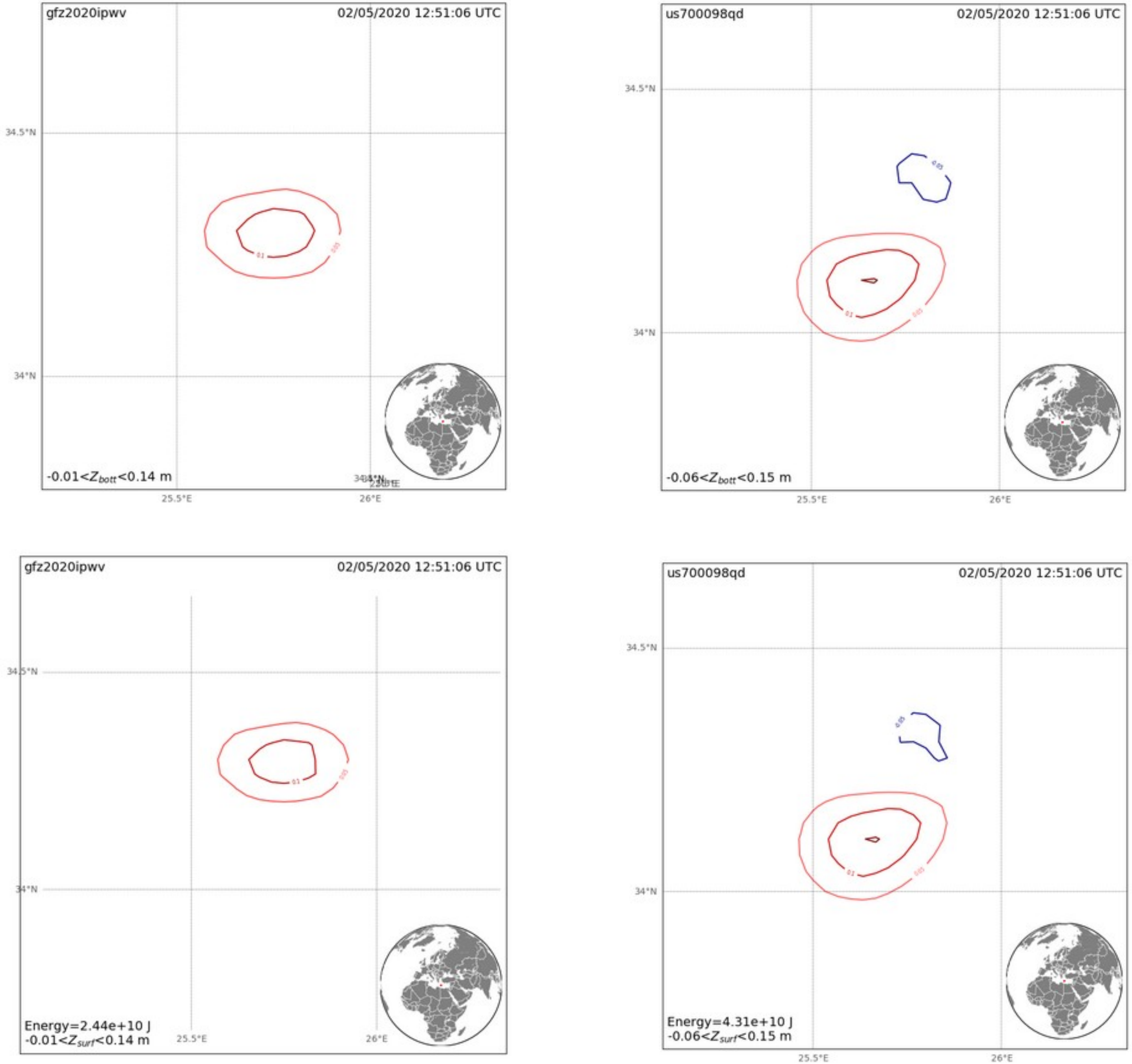
Max water height by NCEI: 0.20 m

According GEOFON

According USGS

Coseismic bottom deformation

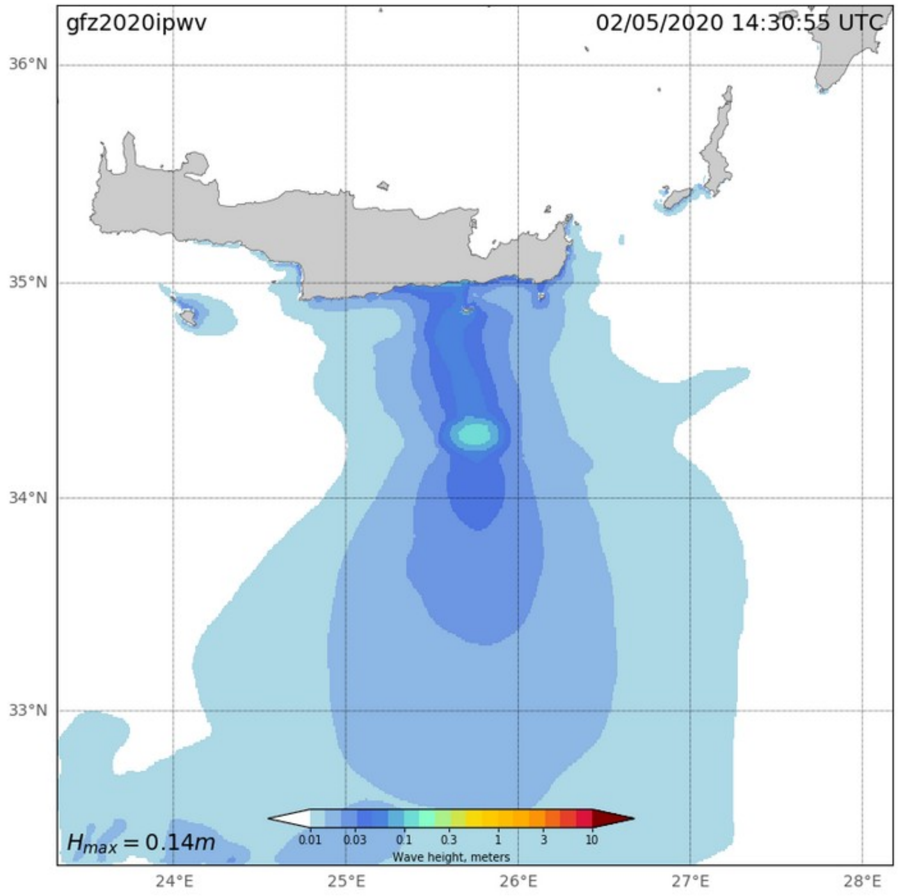
Elevation of water surface



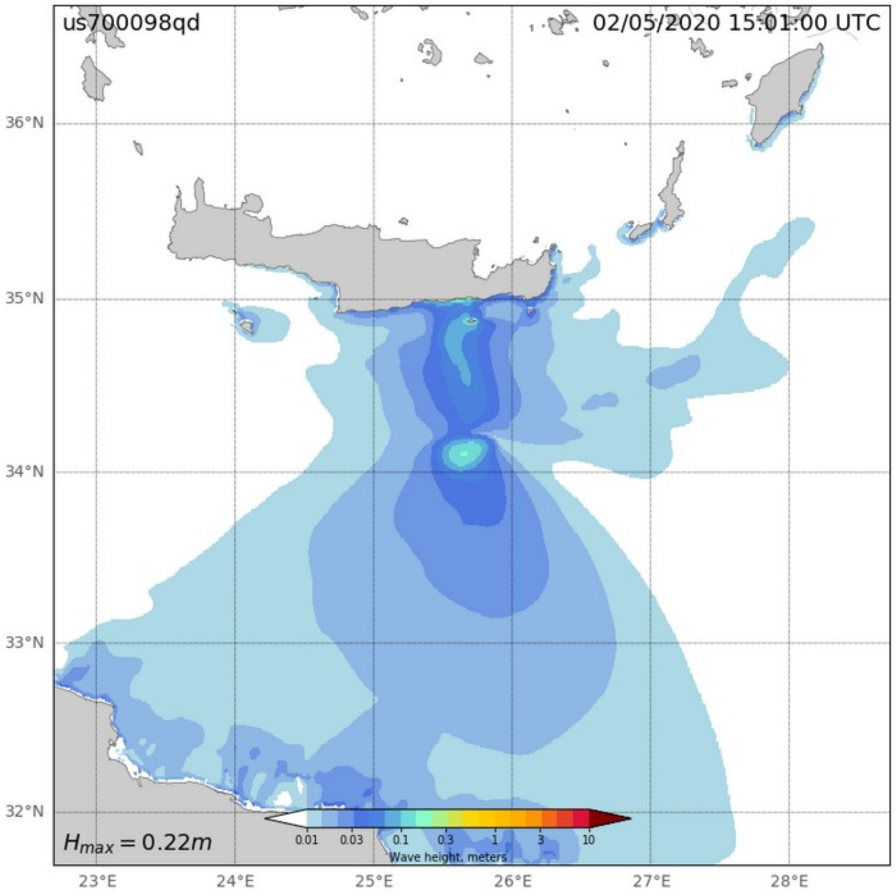
Crete M_w6.6 2 May 2020

Max water height

According GEOFON



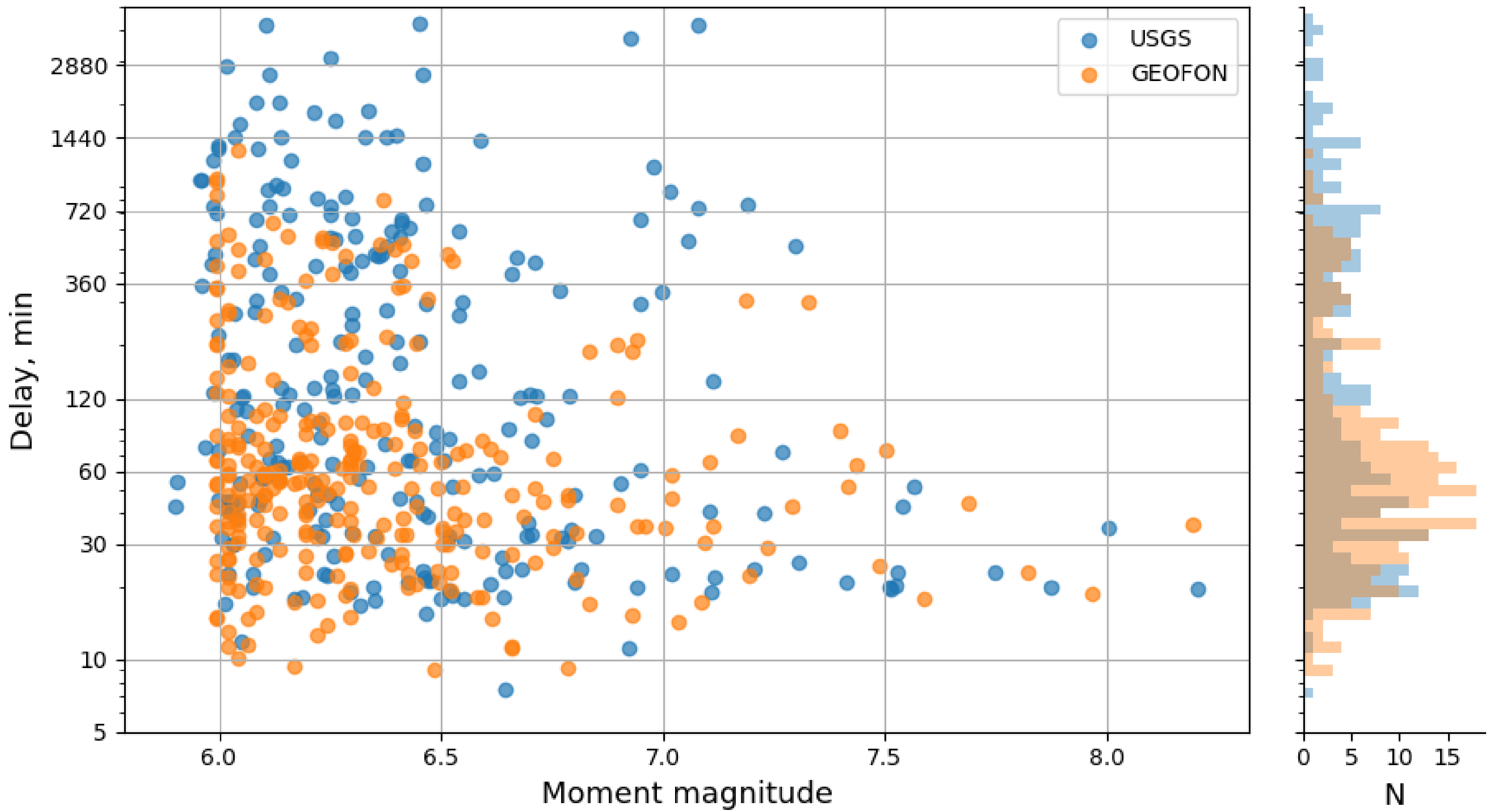
According USGS



Delay of appearance of focal mechanism data

An important factor for the efficiency of assessing the tsunami hazard of an earthquake is the time interval between the earthquake itself and the appearance of data on the source mechanism, depth, magnitude, and coordinates. In case of late appearance of information about the earthquake source and, accordingly, about the tsunami source, the relevance of the tsunami forecast can be completely lost. The Tsunami Observer system is monitoring the time interval between the moments of the beginning of earthquake and the appearance of information about the source mechanism for each processed seismic event.

Delay of appearance of focal mechanism data



Summary since 25 Jan 2018

	According Geofon	According USGS
M_w6+ events	286	256
Events with I_{ts}	64 (22.4%)	64 (25%)
$-2 < I_{ts} < -1$	59	59
$-1 < I_{ts} < 0$	5	5

Tsunami Observer

http://ocean.phys.msu.ru/projects/tsunami-observer/

Kolesov S.V., Nosov M.A. The operating experience of the tsunami observer automatic system for assessment of earthquake tsunami hazard
//Moscow University Physics Bulletin. — 2019. — Vol.74, no.6. — P. 679–689. doi: 10.3103/S0027134919060183

M.A. Nosov, S.V. Kolesov, A.V. Bolshakova, G.N. Nurislamova, K.A. Sementsov, V.A. Karpov Automated system for estimation of tsunami hazard of an earthquake (*in Russian*)
//Memoirs of the Faculty of Physics, Lomonosov Moscow State University. — 2018. — № 5. — P.1850901–1–1850901–9.