The earthquake of October 30th, 2020 at Samos, Eastern Aegean Sea, Greece

Kalogeras, I., Melis, N.S. and Kalligeris, N.
[Preliminary Report], National Observatory of Athens, Institute of Geodynamics

Introduction

At 13:51 local time (11:51 UTC) October 30, 2020 a strong earthquake of magnitude M_L 6.7 (M_w 6.9) occurred off the northern coasts of Samos Island, Eastern Aegean, Greece and 20km NW from the city of Samos. The epicenter coordinates were calculated at the Institute of Geodynamics, National Observatory of Athens (NOAIG) to 37.9001°N, 26.8057°E and the focal depth to 12km (MT centroid depth 8km), respectively. The earthquake caused 2 deaths on the island of Samos and 19 injuries and over of 120 deaths and hundreds of injuries at the town of Izmir (Turkey) as well as a lot of damage on houses, buildings and infrastructures. It was felt at a wide area including Athens (270 km away) and the city of Heraklion, Crete (320 km). A tsunami was generated producing minor damage at the surrounding coasts and especially in the towns of Vathi - Samos (Greece) and Sigacik (Turkey).

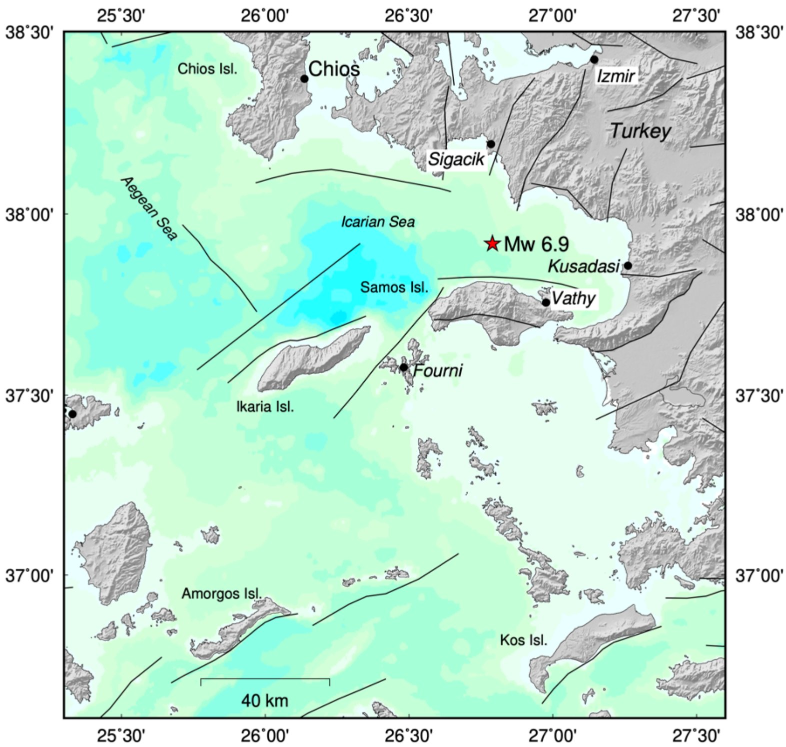


Figure 1. Map of the epicentral area. Red star denotes the epicenter (ref. http://bbnet.gein.noa.gr). Faults lines are shown from GEM fault database (https://blogs.openquake.org/hazard/global-active-fault-viewer/).

Strong motion data

NOAIG strong motion network (http://accelnet.gein.noa.gr) recorded the event. Strong motion data were used for both the automatic and manual/revised location procedure at NOAIG, as well as for the Moment Tensor inversion and the estimation of strong ground motion peak values.

Figure 2 shows the seismic activity around the epicentral area during the first days after the occurrence of the main shock (30/10/2020 – 04/11/2020), as this is resulted from the NOAIG routine analysis. The main seismic activity expands to the North, NW and East of the island with an almost E-W geographical coverage.

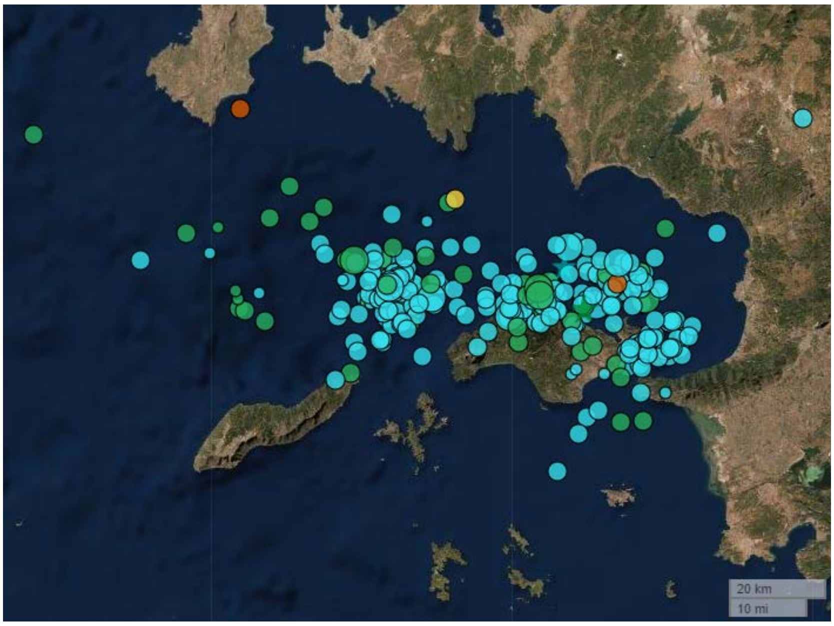


Figure 2. The seismic activity up to November 4, 2020. The star (hardly visible to the central North of the cluster) notes the main shock, while the second at the center of the cluster closer to the Samos Isl. coast marks the strongest aftershock till today (ref. https://bbnet.gein.noa.gr/HL/seismicity/real-time-seismicity/).

Figure 3 shows the focal mechanism solution corresponding to a normal seismogenic fault with an almost E-W strike.
The NOAIG strong motion station on the Samos Island, at the town of Vathi, is equipped with an 11bit QDR instrument in triggering operation, which recorded the main shock, as well as the strongest so far aftershock that occurred just a few hours afterwards, with a magnitude of M_L 5.0. None of the other triggering-mode instruments located at the surrounding islands were triggered. On the contrary, the main event and the aftershocks were recorded by all the modern 24bit instruments of Guralp CMG-5TDE type in operation, up to long distances. They are continuously recording instruments that transmit data in real time. The data are processed either within an automatic near real time procedure (routine analysis of seismicity, RRSM mode using SeisComP3 scwfparam plugin and followed by ShakeMap 4.0 application) or manually, usually in short time after the occurrence of a strong earthquake.
The preliminary record processing, which is presented here (Figures 4-7, Table I), include the strong motion records from the Samos strong motion instrument, which is installed at the basement of the 3-storey R/C Prefecture building at Vathi-Samos, as well as the PGA values from other instruments at distances up to 380km, used for indicative reasons.

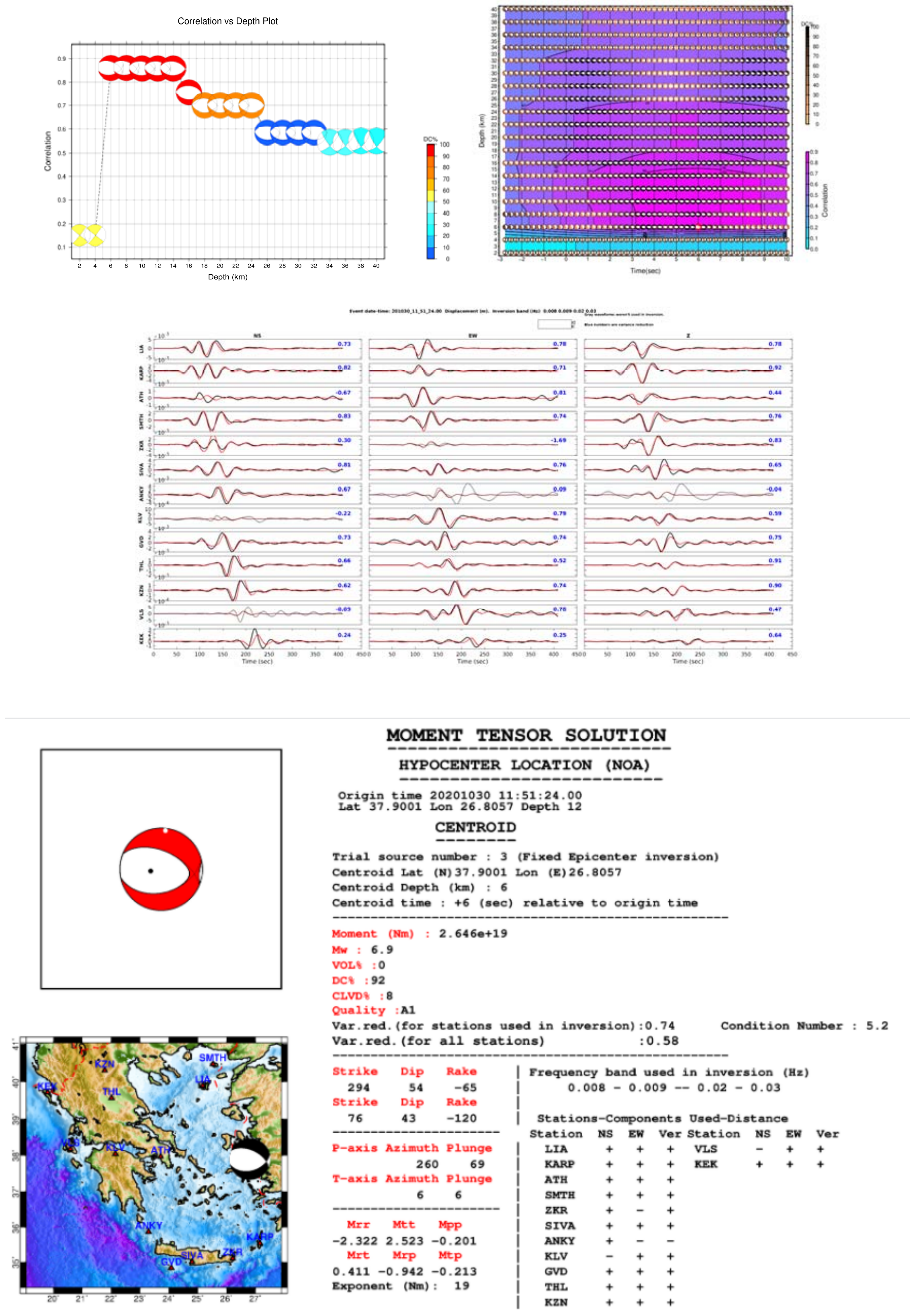


Figure 3. The MT - focal mechanism solution showing a predominant normal fault (ref. https://bbnet.gein.noa.gr/mt_solution/2020/201030_11_51_24.00_MTsol.html).

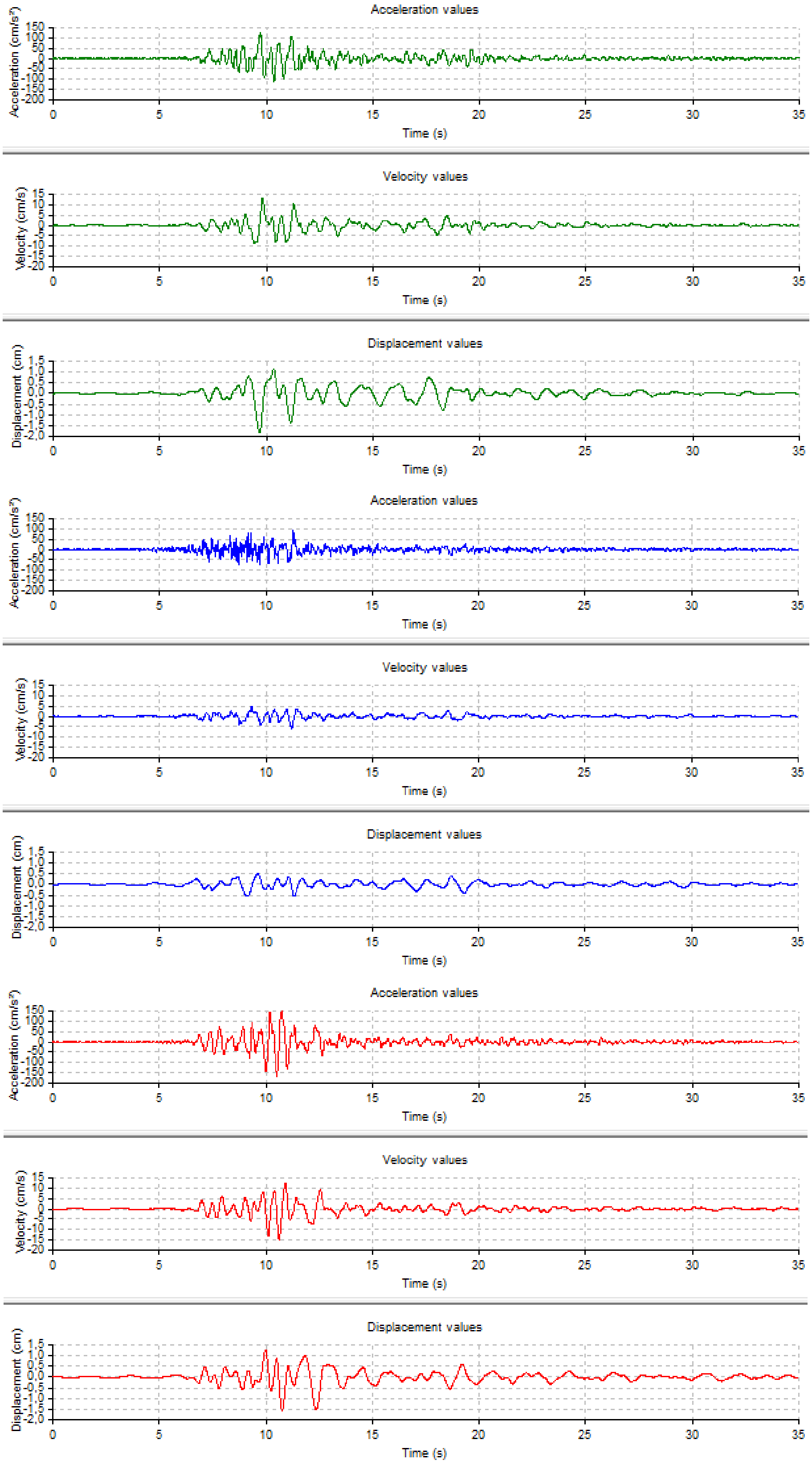


Figure 4. The main shock processed record. From top to bottom the acceleration, velocity and displacement time histories for the Longitudinal (green), the Vertical (blue) and the Transverse (red) components. The peak values are 122.1, 93.1 and 169.6 cm/s^2 for acceleration, 13, 5.7 and 15.1 cm/s for velocity and 1.8, 0.5 and 1.6 cm for displacement, respectively.

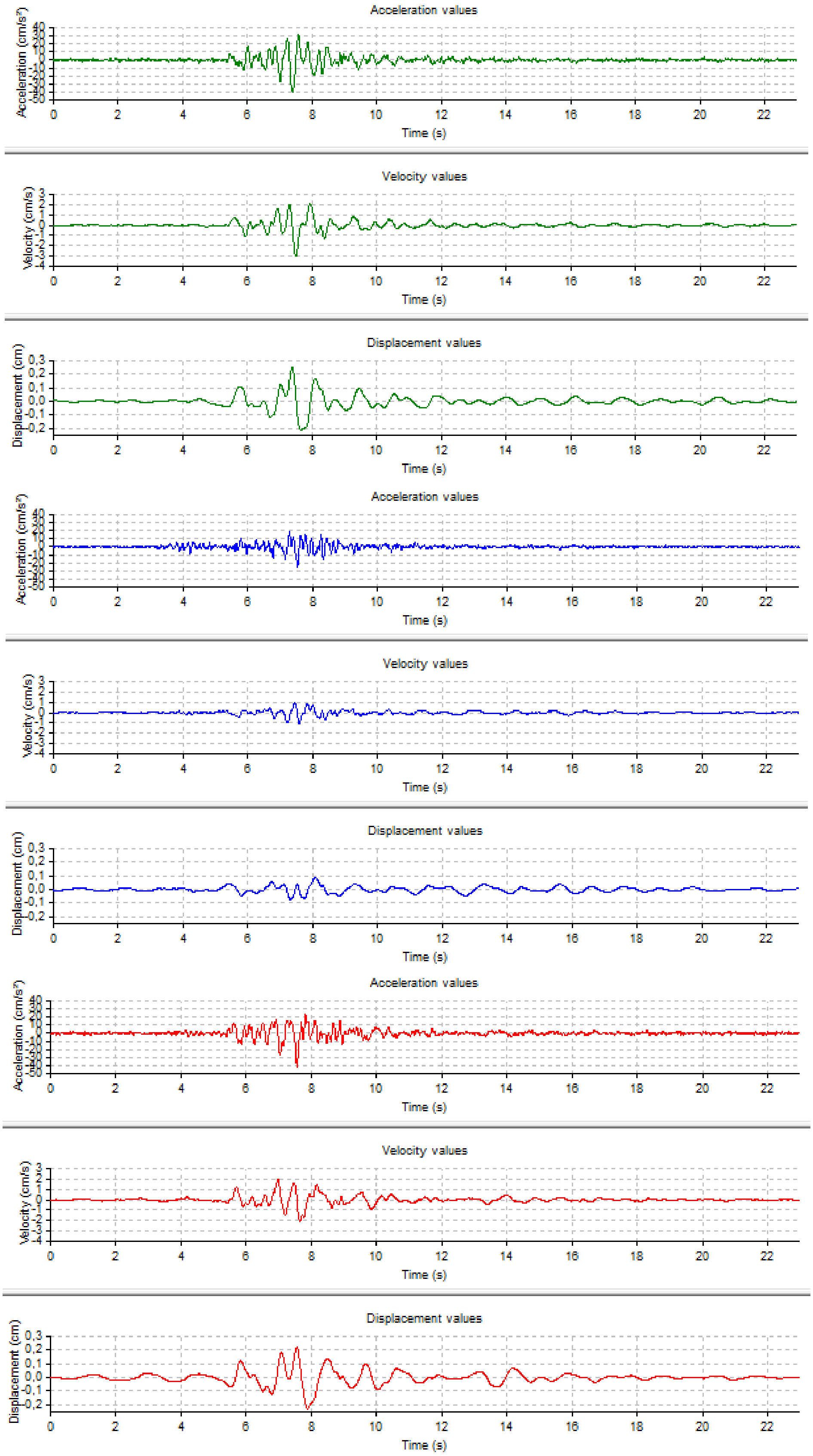


Figure 5. The processed strong aftershock record. From top to bottom as in figure 4. The peak values are 39.6, 24.9 and 41.5 cm/s^2 for acceleration, 3.0, 1.1 and 2.0 cm/s for velocity and 0.2, 0.1 and 0.2 cm for displacement, respectively.

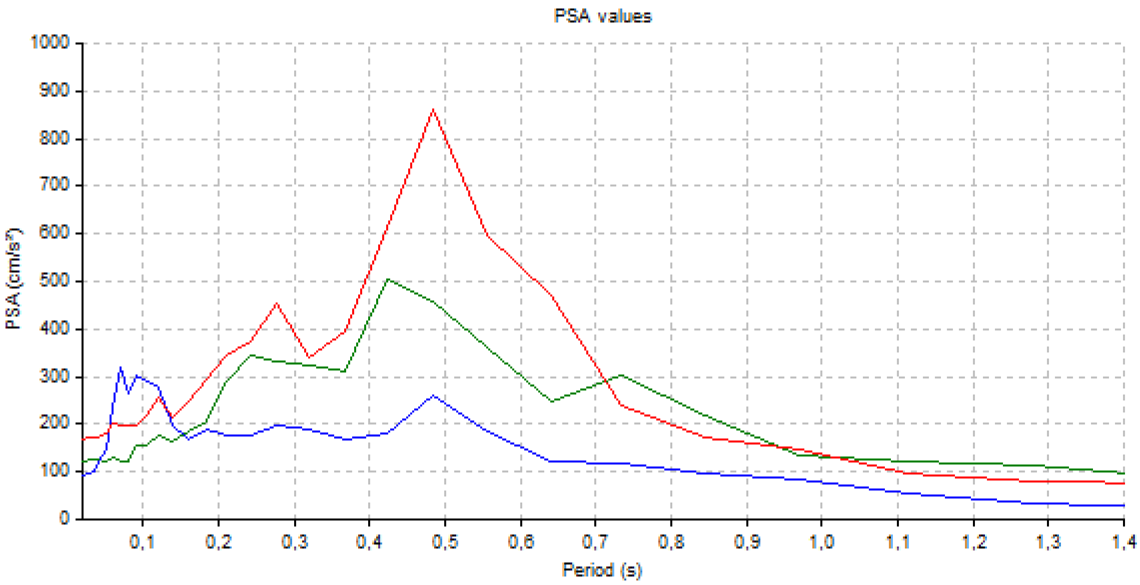
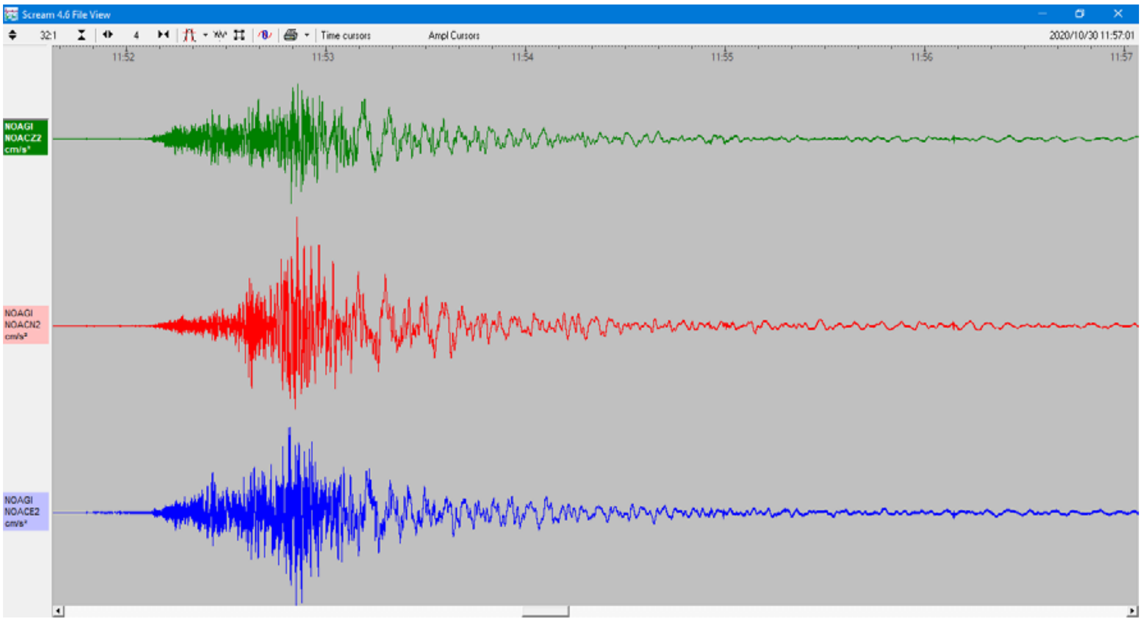


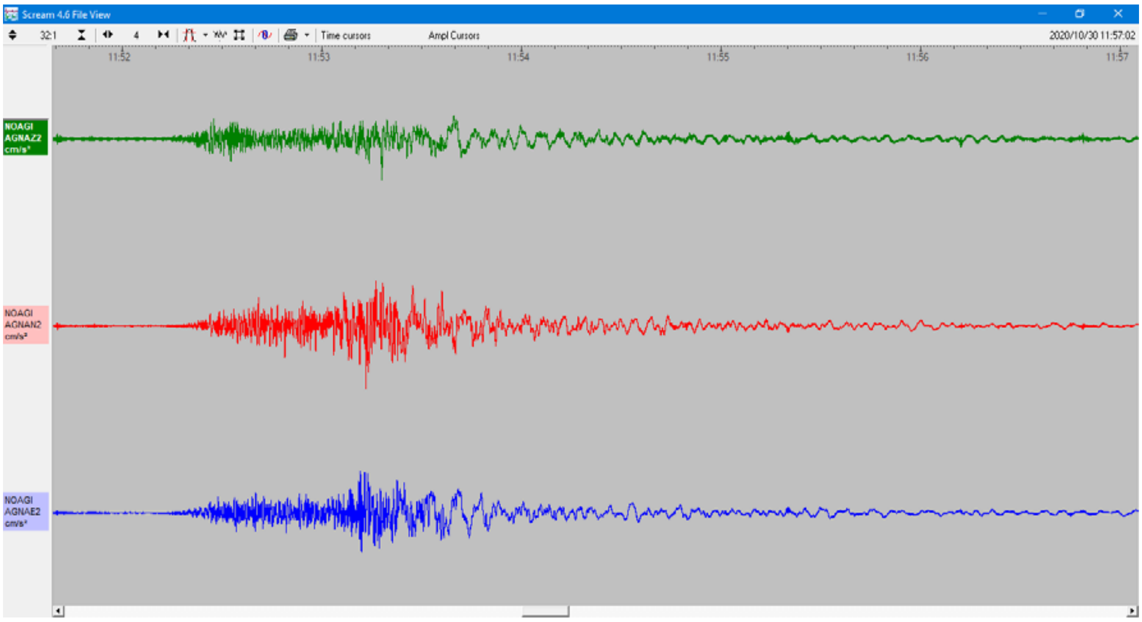
Figure 6. The spectral acceleration diagram for the main shock. Green, blue and red stand for the L, V and T components, respectively. The T component shows a maximum at 0.5s (2Hz), while the V component shows a maximum at 0.1s (10Hz).

Table I. Information about the strong motion stations and the PGA values calculated from the preliminary processing of the strong motion records, for indicative purpose. The location of the instruments and some information about the stations can be found at https://accelnet.gein.noa.gr/station-information/.

Station Code	Location / Building	Soil Conditions	Distance (km)	PGA (cm/s^2)		
				Z	X	Y
SAMA	Samos / Prefecture	soft rock	19	93.1	122.1	169.6
KLNA	Kalymnos / Hospital	rock	112	17.6	24.9	23.9
TNSA	Tinos / Town Hall	alluvium	153	15.4	25.1	19.7
ASTA	Astypalaia / Town Hall	rock	160	3.8	4.7	3.8
THRA	Thira / Town Hall	alluvium	209	24.6	31.3	37.7
EFSA	Aghios Efstratios / Town Hall	alluvium	238	2.2	2.1	2.5
MILA	Milos / Town Hall	soft rock	249	14.5	21.1	23.7
LIAA	Limnos / Seismic Station	rock	260	1.0	1.8	1.9
NOAC	Athens / Seismic Station	rock	273	2.4	3.6	4.2
AGNA	Aghios Nikolaos / OTE	soft rock	322	1.5	1.6	2.1
ALXA	Alexandroupolis / Nat. Hist. Museum	alluvium	335	1.2	2.3	2.9
DLFA	Delphoi / Town Hall	rock	382	0.5	0.7	0.7



(a)



(b)

Figure 7. Indicative records at two regional-distance stations, where the main shock was felt, namely: *(a)* Athens (NOAC) with an epicentral distance of 270 km and *(b)* Aghios Nikolaos, Crete (AGNA) with an epicentral distance of 320 km. A long period wave at the end of the strong motion record is clearly apparent, which is present in the majority of the records at regional-distance.

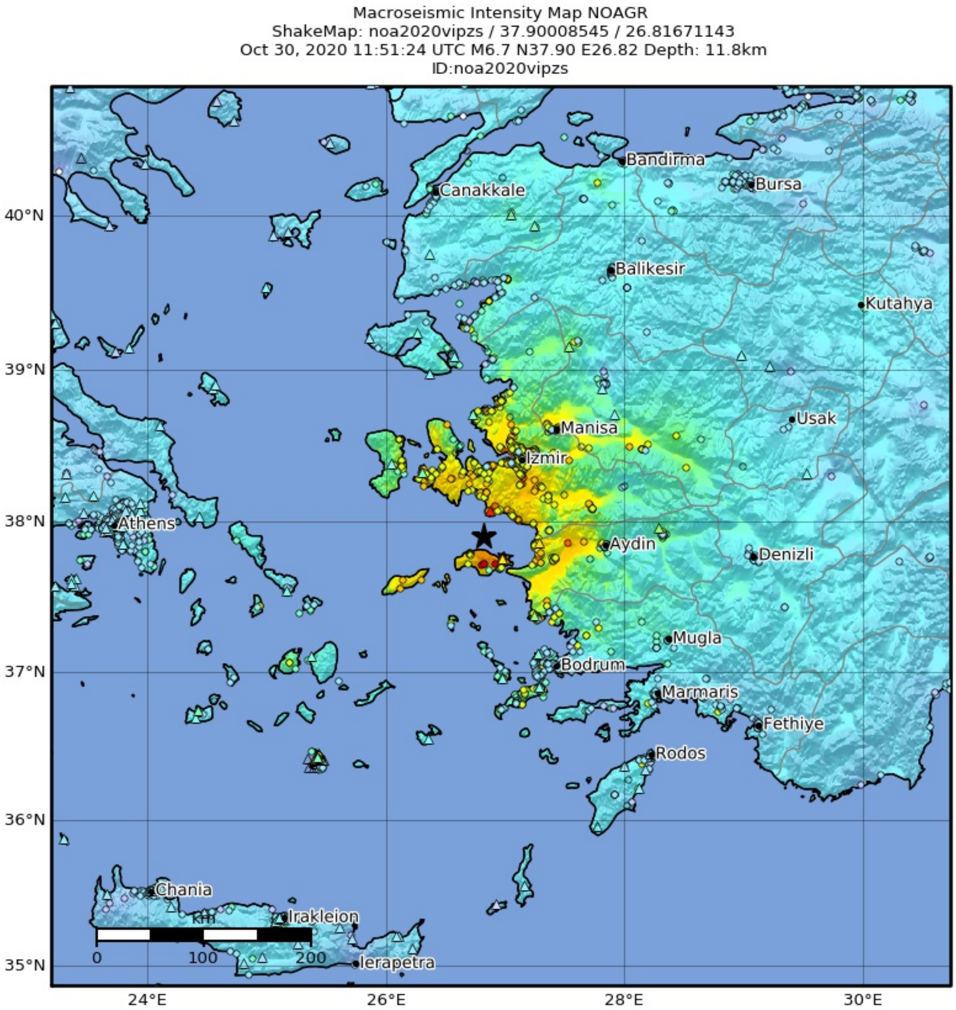
Preliminary ShakeMap application

Using SeisComP3 with the scwfparam plugin in real time seismicity monitoring, NOAIG routinely produces parametric data which are fed as input to a ShakeMap 4 application procedure. This also includes similar parametric data produced by ITSAK and/or other agencies and made available after a strong event. Depending on the felt severity of the event, EMSC testimonies are also included in the same procedure, thus enhancing areas where instrumental data are lacking. In our case we used:

ITSAK (http://shakemaps.itsak.gr/auth2020vimx/intensity.html),

KOERI (http://eida.koeri.boun.edu.tr/) and

AFAD (https://tadas.afad.gov.tr/event-detail/11995) parametric data, as well as EMSC testimonies data (https://www.seismicportal.eu/testimonies-ws/) to enhance a resulted intensity map showed in Figure 8. Figure 9 presents a map of PGA contours of the main shock.



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 20: Processed 2020-11-05T15:24:39Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Figure 8. An automatic reproduced intensity ShakeMap, using NOAIG, ITSAK, KOERI and AFAD strong motion reported data (solid triangles indicate the stations reporting values and colored according to intensity). EMSC testimonies are also used (solid circles colored according to reported intensity).

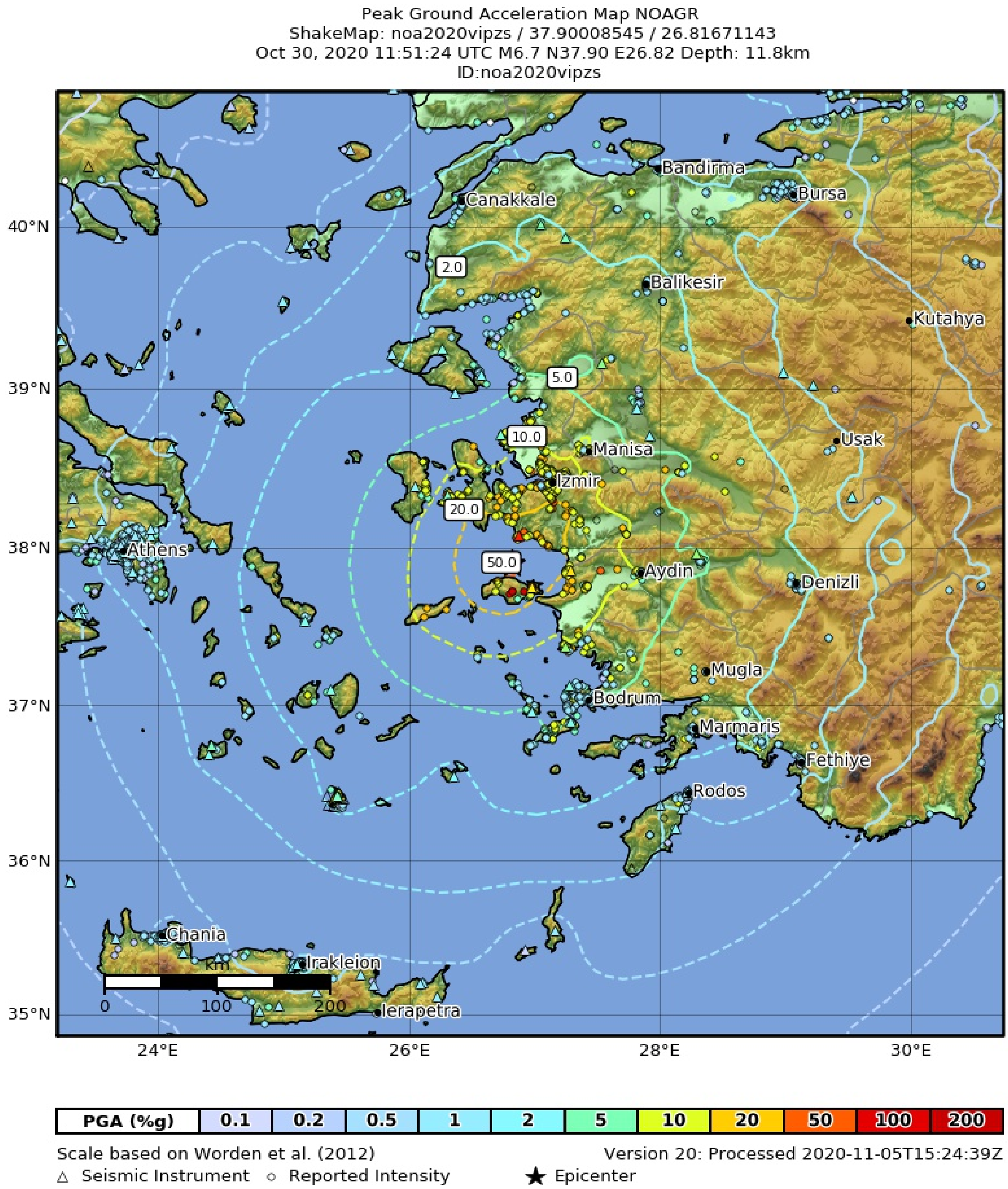


Figure 9. An automatic reproduced PGA ShakeMap, using NOAIG, ITSAK, KOERI and AFAD strong motion reported data (solid triangles indicate the stations reporting PGA values and colored accordingly). EMSC testimonies are also used (solid circles colored according to reported intensity converted to PGA using GMICE proposed by Worden et al. (2012)).

Preliminary tsunami observations and modeling

Following the earthquake on the 30th of October 2020, a tsunami was generated from the produced co-seismic deformation. The impact of the tsunami was most prominent inside the Ikarian Bay, affecting the north coasts of Samos Island and the Turkish coasts along the coastal stretch between Alacati and Kusadasi. According to preliminary post-tsunami survey data, the tsunami impact was largest in Sigacik on the Turkish coast, and in the cities of Karlovasi and Vathy on the north coast of Samos Isl. (Figure 10).

Figure 10. Pictures from the tsunami aftermath in Karlovasi (left) and Vathy (right), both located along the north coast of Samos Isl. The left picture shows tsunami deposits (sand and gravel) next to the harbor of Karlovasi and the displacement of a football post by the water flow; the flow direction of the last water retreat can be inferred from the branches trapped on the steel post. The right picture shows the flow depth at the shop window (~95 cm) in the streets of the city of Vathy.

The Hellenic National Tsunami Warning Center (HL-NTWC) operating at NOAIG, issued the first tsunami warning message (TWM) 11 minutes after the earthquake (at 14:02 local time). The tsunami alert levels assigned in the first TWM were *local tsunami watch* (distance ≤ 100 km from epicenter), *regional tsunami watch* (100 < distance ≤ 400 km from epicenter), and *basin-wide advisory* (distance > 400 km from epicenter), which are based on the preliminary earthquake parameters and the UNESCO/ICG/NEAMTWS Decision Matrix. A tsunami ongoing message was issued by the HL-NTWC at 15:23 local time, following the arrival of the tsunami at the nearest tide gauges in the cities of Kos (Kos Isl.) and Plomari (Lesvos Isl.) (Figure 11).

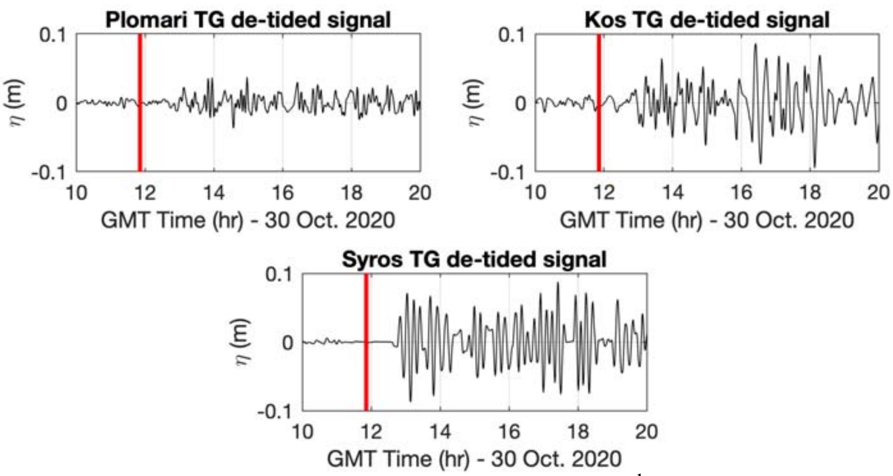


Figure 11. De-tided tide gauge recordings of the October 30th, 2020 Samos-Izmir tsunami at the three nearest tide gauges. The raw signal was filtered within the 240 – 3600 s frequency band to compute the residual (de-tided) signal. The tide gauges of Plomari (on Lesvos Island) and Kos (on Kos Island), provided by the Joint Research Center, belong to the tide gauge network of NOAIG, and the tide gauge of Syros (on Syros Island) is part of the tide gauge network of the Hellenic Hydrographic Service.

Figure 12 shows preliminary numerical simulation results using the Method Of Splitting Tsunami (MOST) hydrodynamic model (Titov and Synolakis, 1998); the initial conditions for the simulation were derived from the finite-fault model solution published by USGS (https://earthquake.usgs.gov/earthquakes/eventpage/us7000c7y0/executive, using the south-dipping fault plane). The maximum wave amplitude distribution shows how the wave energy is mostly contained inside the Ikarian Bay. Wave energy propagates out in the Aegean Sea and impacts to a much lesser extent the islands of Mykonos, Tinos and Andros.

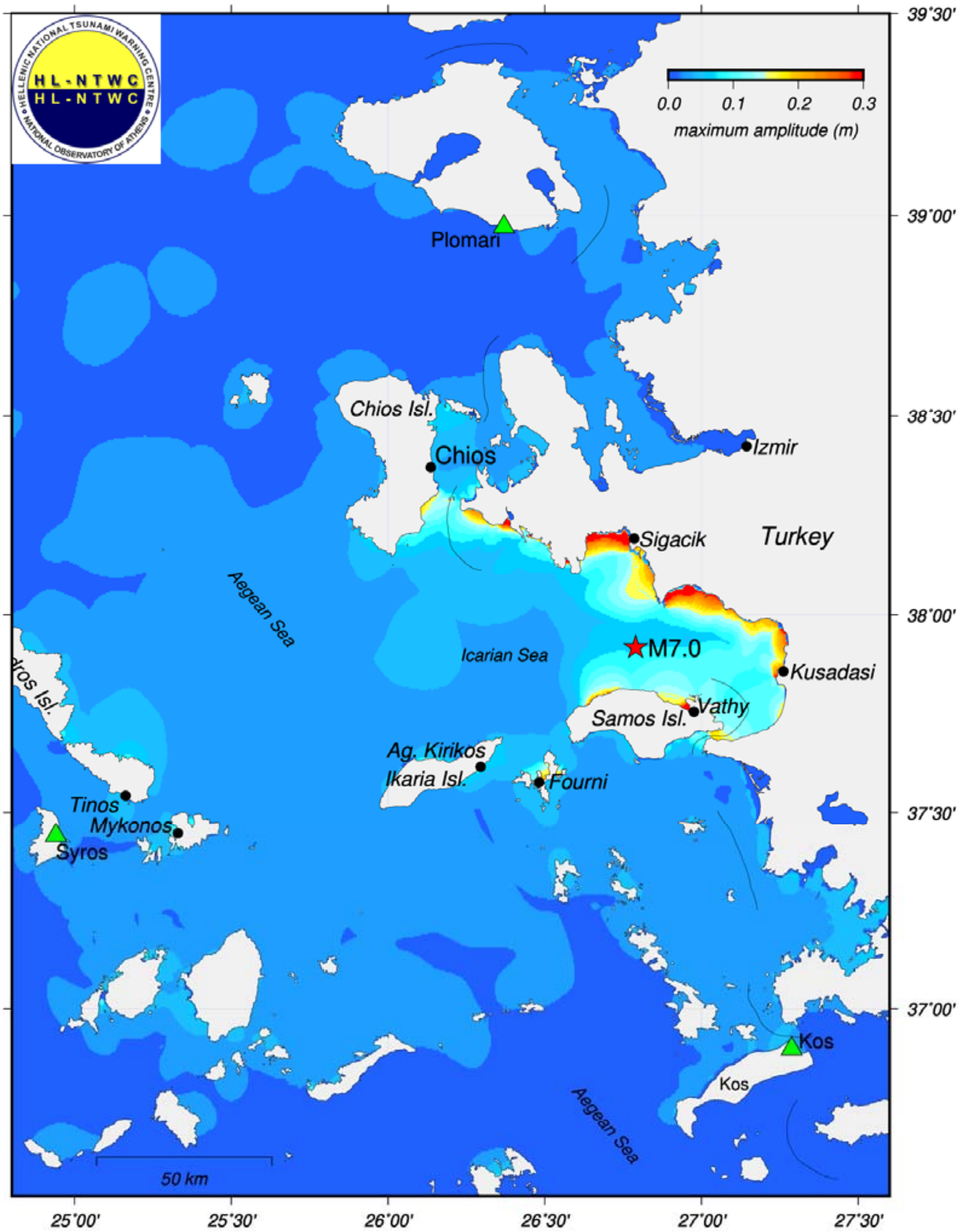


Figure 12. Map showing maximum wave amplitude of the October 30th tsunami computed using the MOST hydrodynamic model - initial conditions for tsunami generation correspond to the USGS finite-fault (south-dipping) model. Locations of the tide gauges nearest to the earthquake epicentre (presented in Figure 11) are shown with the green triangles.

Acknowledgements

The authors would like to acknowledge the research, scientific and technical staff of NOAIG for their contribution to the operational services of the Institute. The maps of figures 1, 8, 9 and 12 were drawn using the Generic Mapping Tools.

References

Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences and gempa GmbH (2008). The SeisComP seismological software package. GFZ Data Services. doi:10.5880/GFZ.2.4.2020.003.

Titov, V.V., and C.E. Synolakis (1998): Numerical modeling of tidal wave runup. *J. Waterw. Port C-ASCE*, 124(4), 157-171.

Wessel, P., Luis, J. F., Uieda, L., Scharroo, R., Wobbe, F., Smith, W. H. F., & Tian, D. (2019). The Generic Mapping Tools version 6. *Geochemistry, Geophysics, Geosystems*, 20, 5556–5564.

Worden, C. B., M. C. Gerstenberger, D. A. Rhoades, and D. J. Wald (2012). Probabilistic relationships between ground-motion parameters and modified Mercalli intensity in California, *Bull. Seismol. Soc. Am.*, 102, no. 1, 204–221

Worden, C.B., E. M. Thompson, M. Hearne, and D.J. Wald (2020). ShakeMap Manual Online: technical manual, user's guide, and software guide, U. S. Geological Survey. http://usgs.github.io/shakemap/. DOI: https://doi.org/10.5066/F7D21VPQ.