OVERVIEW OF TSUNAMIS FROM DIFFERENT SOURCES IN HELENIC ARC AND EASTERN MEDITERRANEAN

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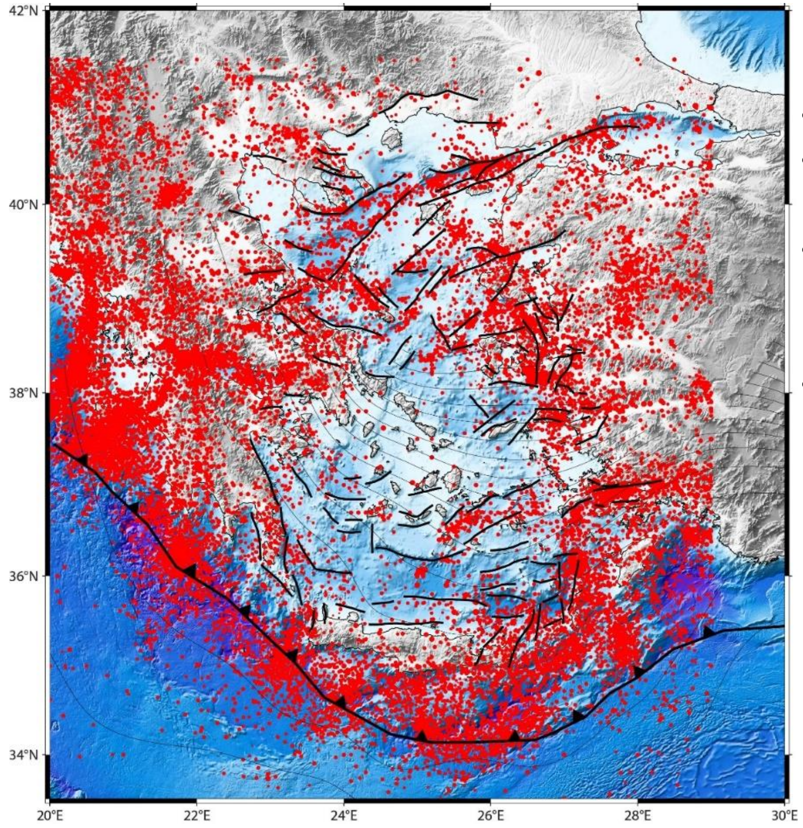
March 18, 2025

TUBITAK 121M750: Probabilistic Fault-Induced Tsunami Occurrence and Hazard Analysis for the Aegean Coast: Online Interactive Tsunami Information System



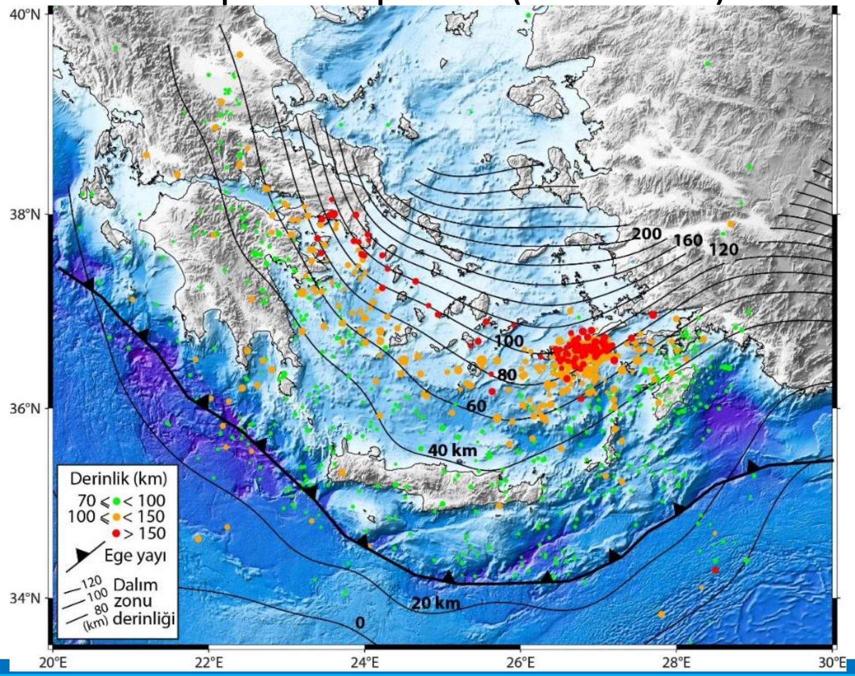
Shallow earthquakes (d < 70 km)

Dogan et al. EGU2023

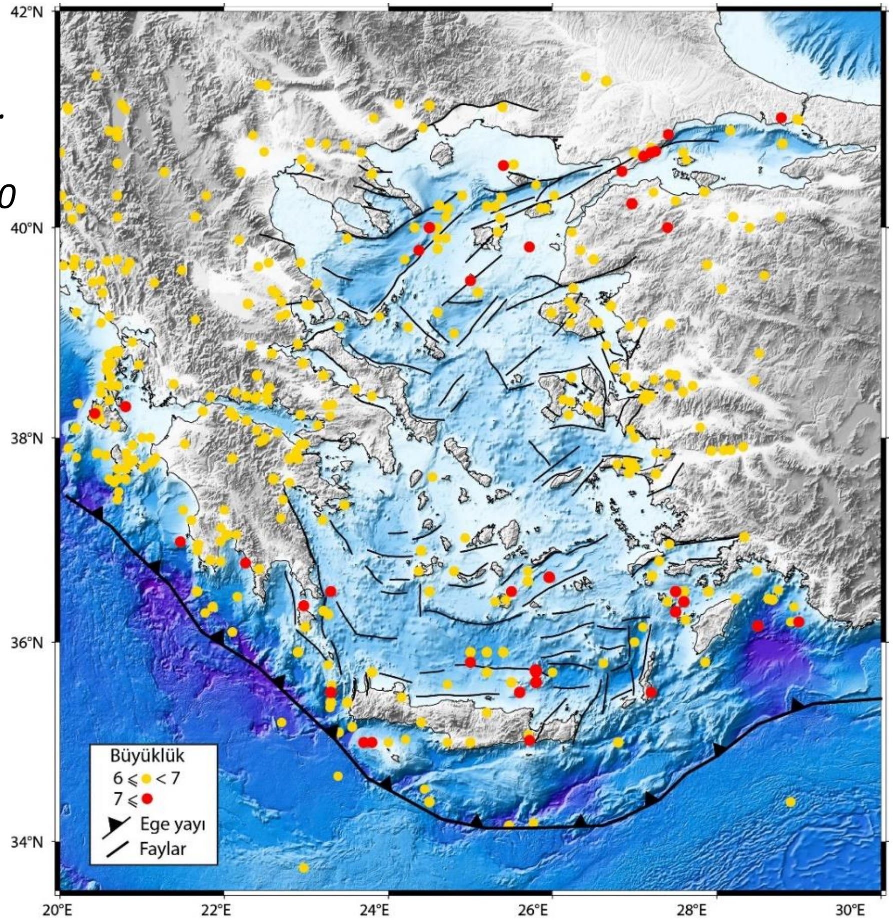
Compiled Earthquake Catalogue

- *Danciu et al. (2021) for 1000-2014*
- *EPICA (European PreInstrumental Earthquake Catalogue, Rovida&Antonucci, 2021) for 1000-1899*
- *EMEC (European-Mediterranean Earthquake Catalogue, Grünthal& Wahlström, 2012; Danciu et al. 2021) for 1900-2014*
- *ISC (International Seismological Centre) for 2014-2020*

Deep earthquakes (d ≥ 70 km)



M>6 earthquakes in the Aegean



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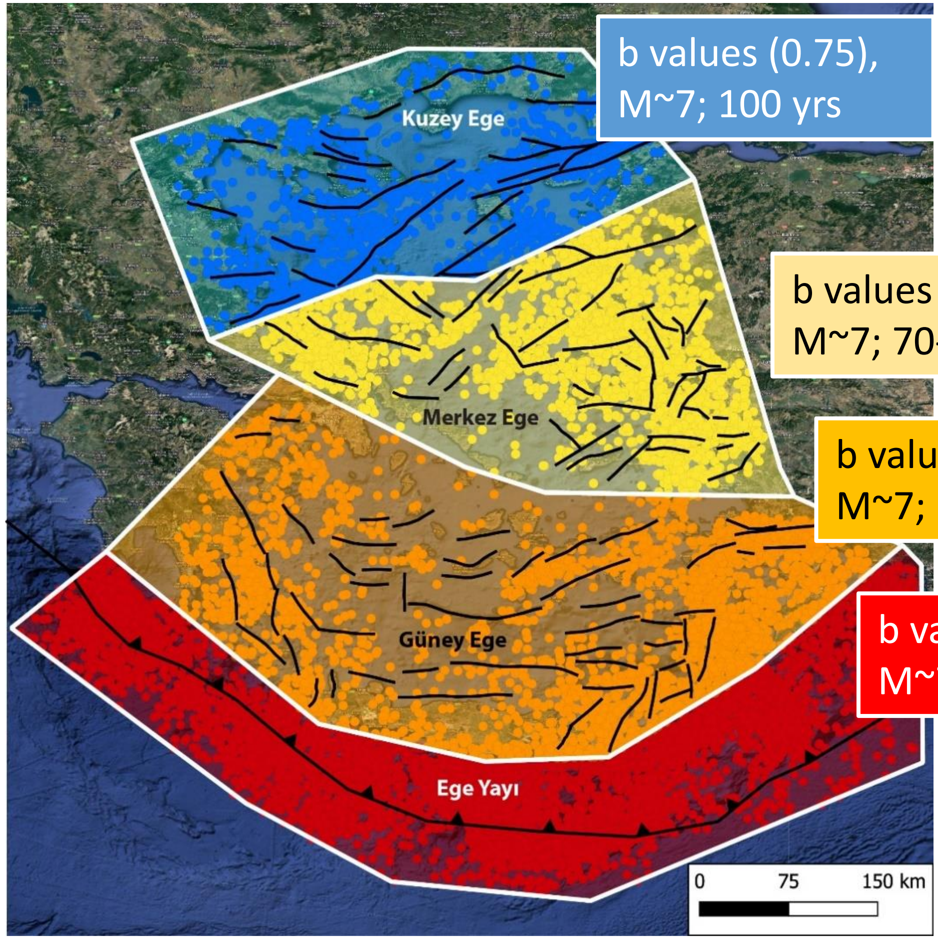
Earthquake Recurrence Periods for four main seismotectonic areas in the Aegean Sea



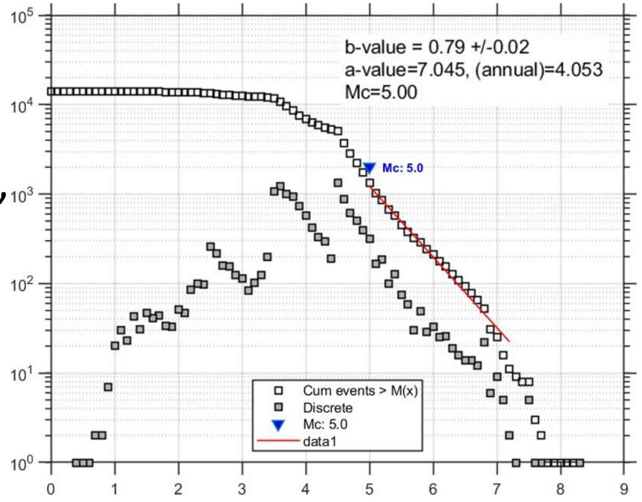
b values (0.75), M~7; 100 yrs

b values (0.69-0.76), M~7; 70-80 yrs

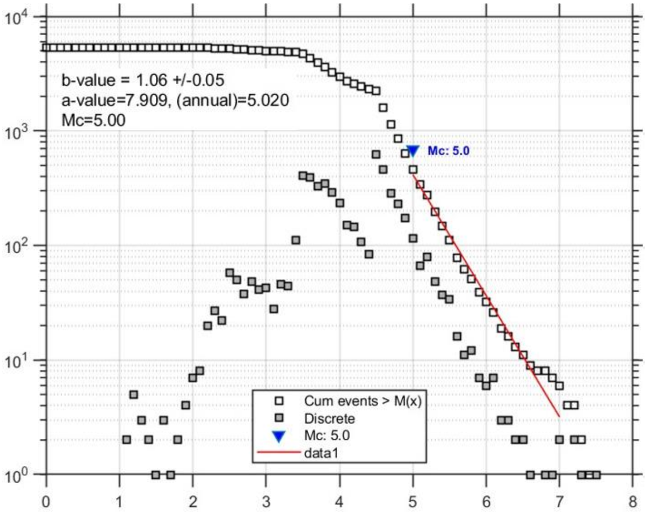
b values (0.67), M~7; 70-80 yrs

b values (0.75), M~7; 70-80 yrs

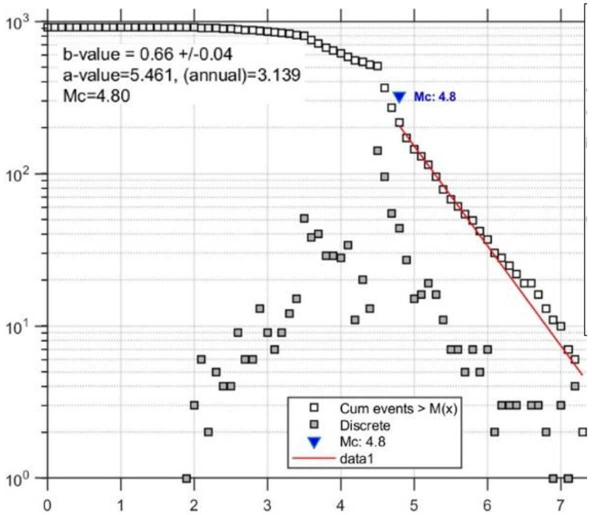
Aegean (North, Central, South)



Shallow Earthquakes



Deep Earthquakes



Aegean Arc

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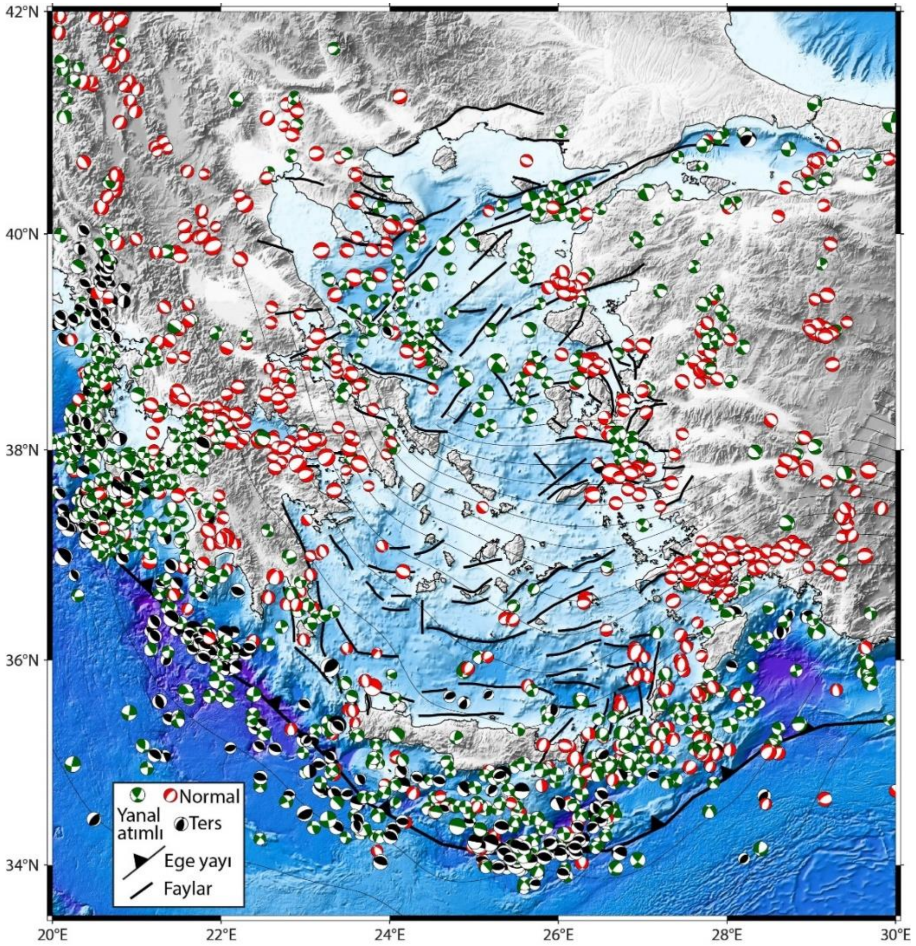
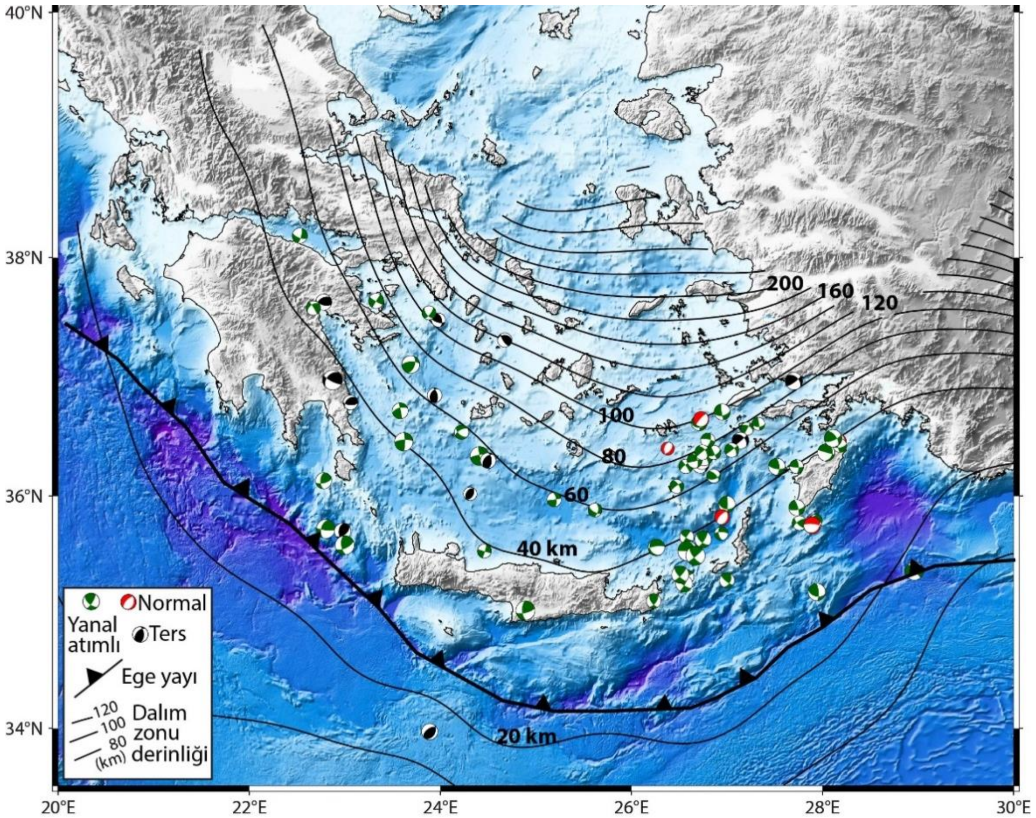
Focal Mechanisms



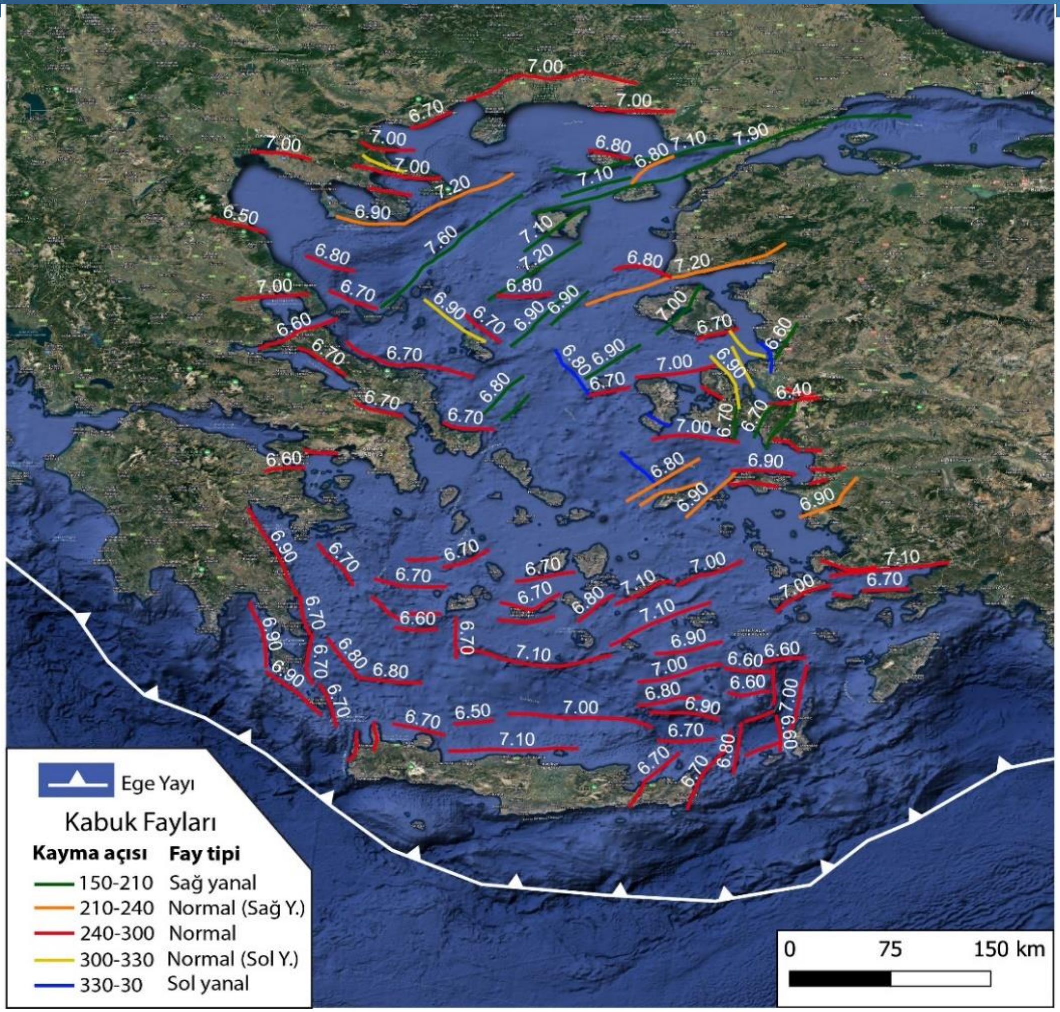
Shallow earthquakes (d < 70 km)

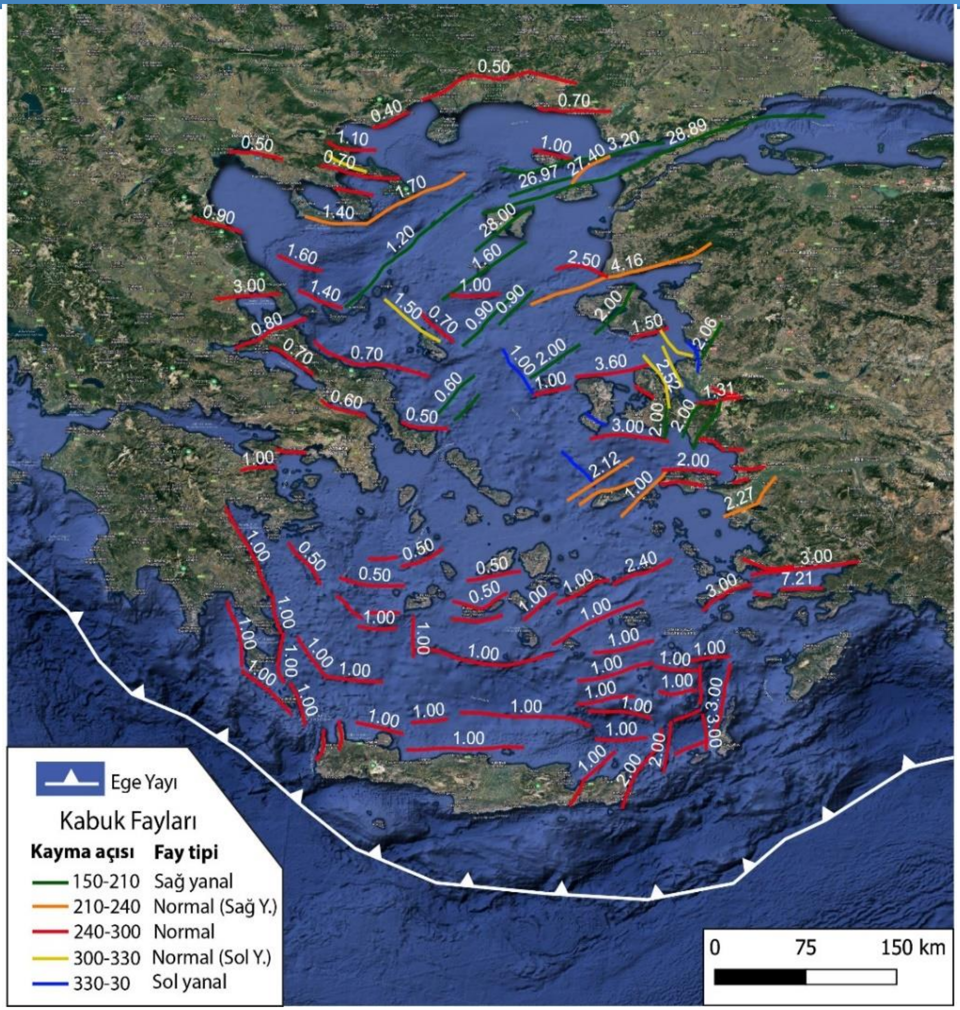
Deep earthquakes (d ≥ 70 km)



ISC Catalogue; Hayes et al. 2018

TUBITAK 121M750: Probabilistic Fault-Induced Tsunami Occurrence and Hazard Analysis for the Aegean Coast: Online Interactive Tsunami Information System





Tectonic maps in the Aegean showing the tsunamigenic faults and associated

Maximum earthquake magnitudes (Mmax) slip rates & fault types

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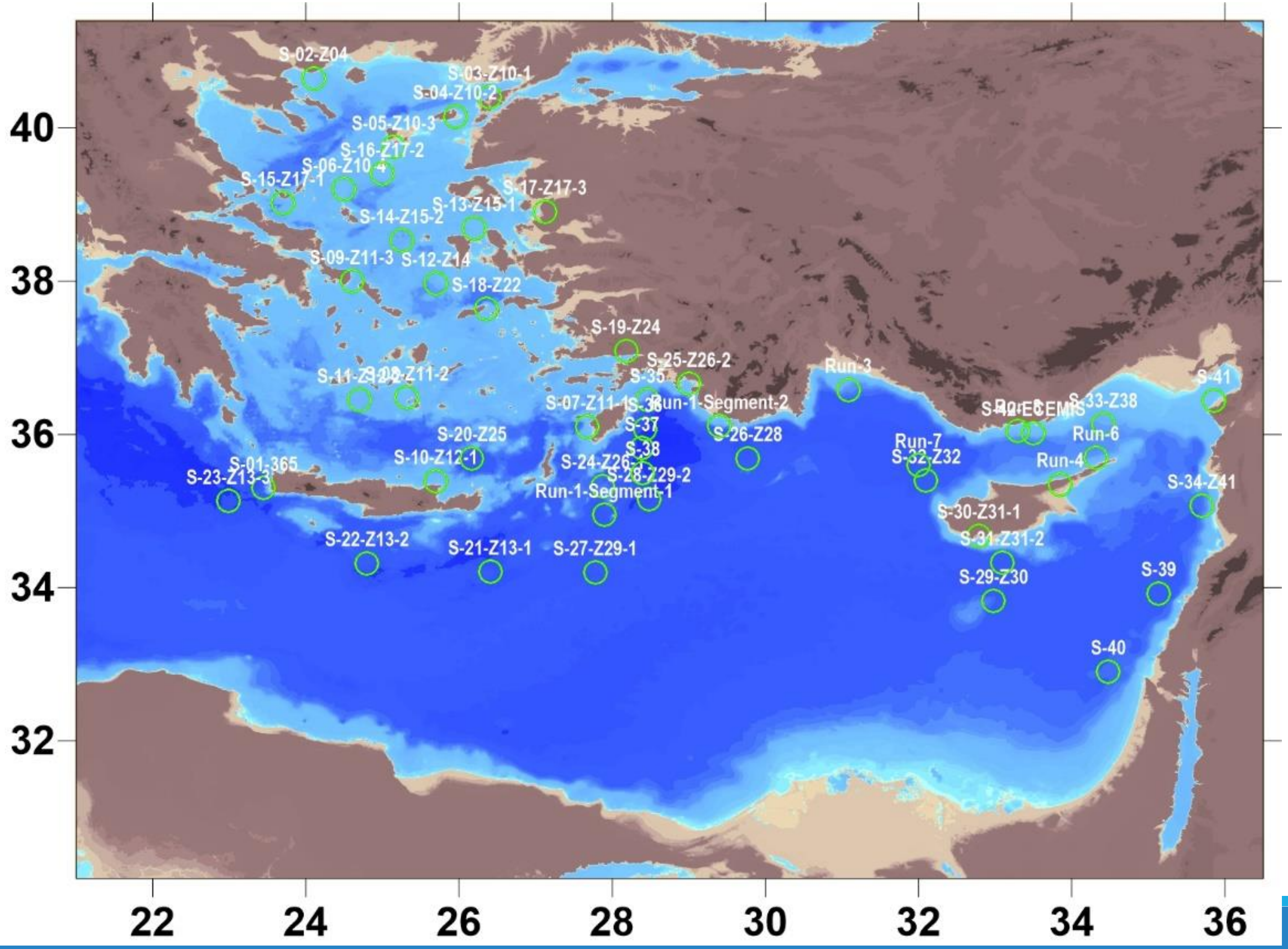
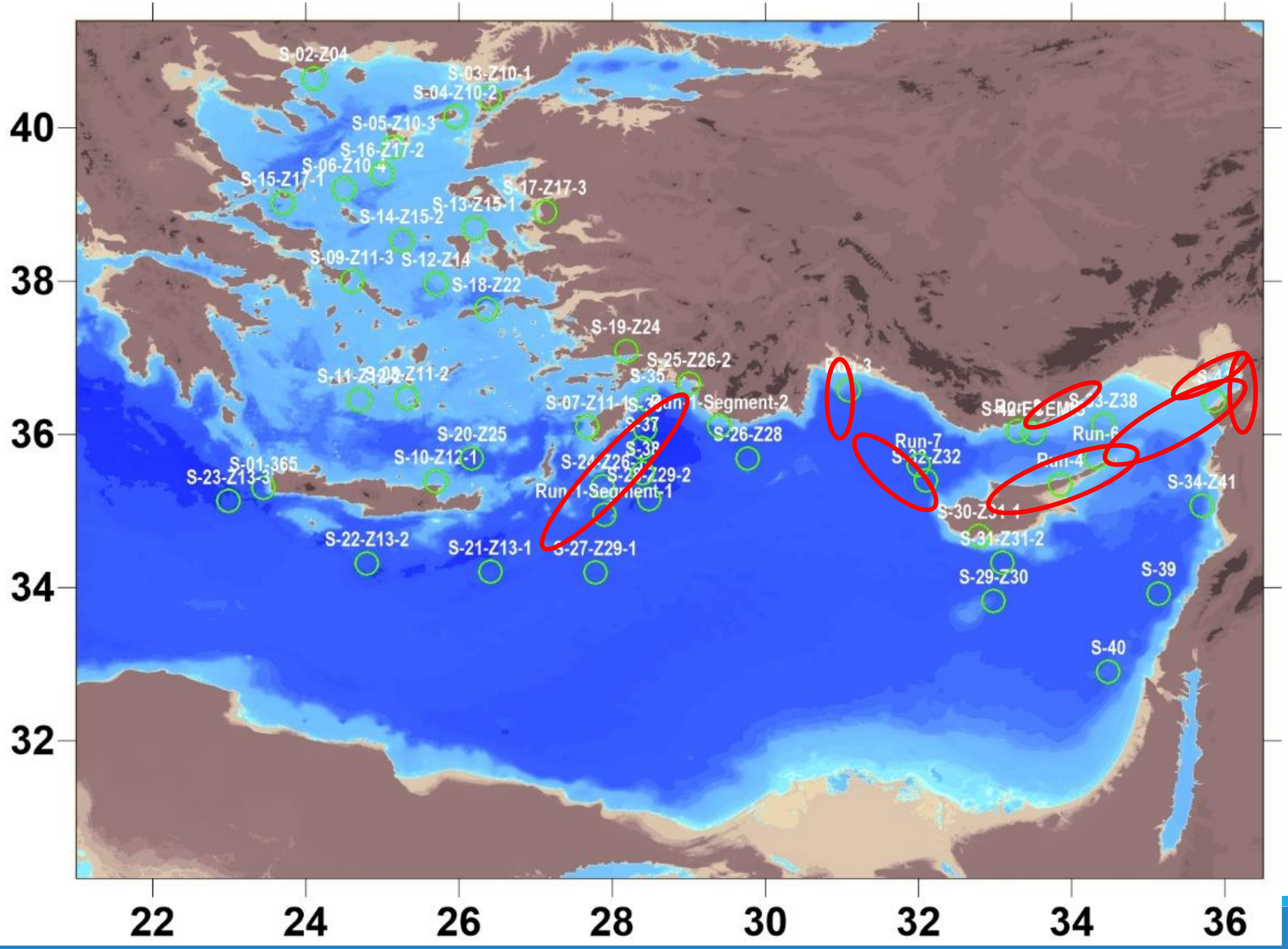
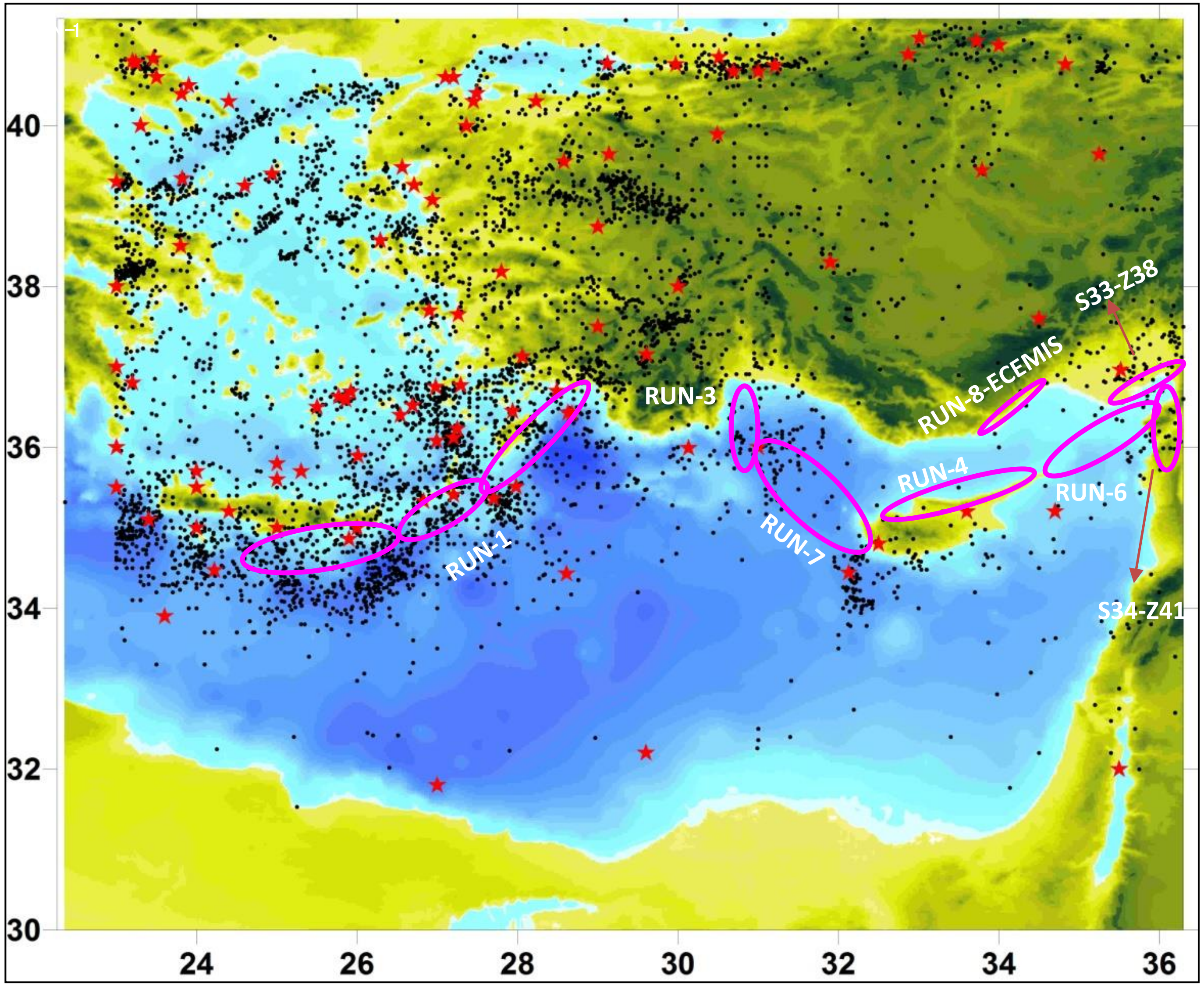
TSUNAMIGENIC SEISMIC ZONES IN EASTERN MEDITERRANEAN



TSUNAMIGENIC SEISMIC ZONES IN EASTERN MEDITERRANEAN



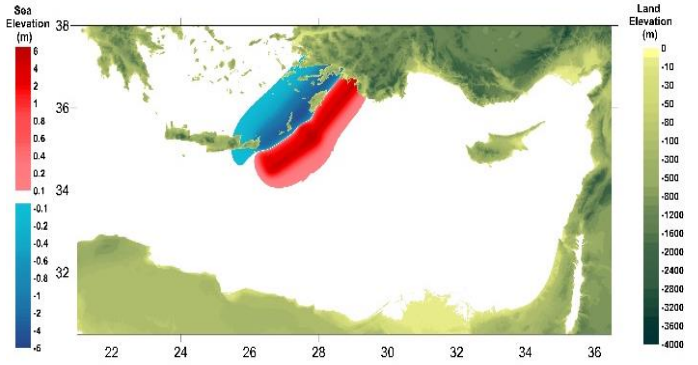
TSUNAMIGENIC SEISMIC ZONES IN EASTERN MEDITERRANEAN

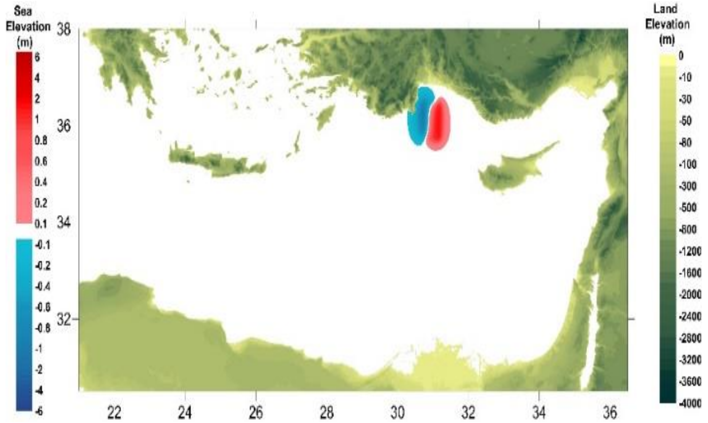


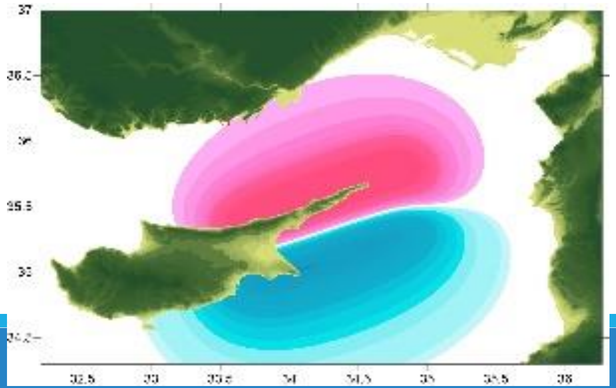
Distribution of earthquake epicenters between 1900-2015

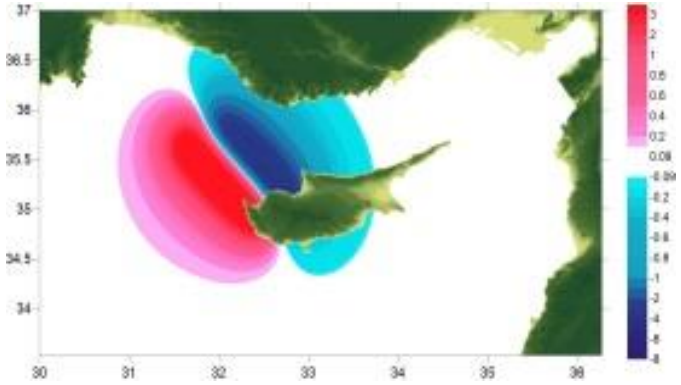
Ellipses show the Locations of Critical Tsunami Scenarios (Black dots represent earthquakes with magnitude between 4 and 6; Red Stars indicate earthquakes with the magnitude of greater than 6).

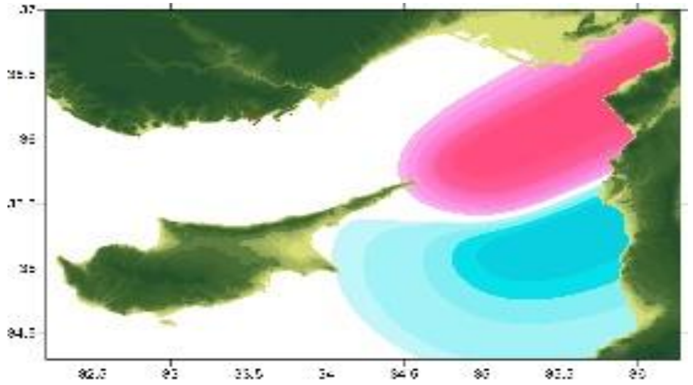
INITIAL SEA STATES FOR SOME OF THE CONSIDERED SOURCES IN SOUTHERN ANATOLIA-EASTERN MEDITERRANEAN

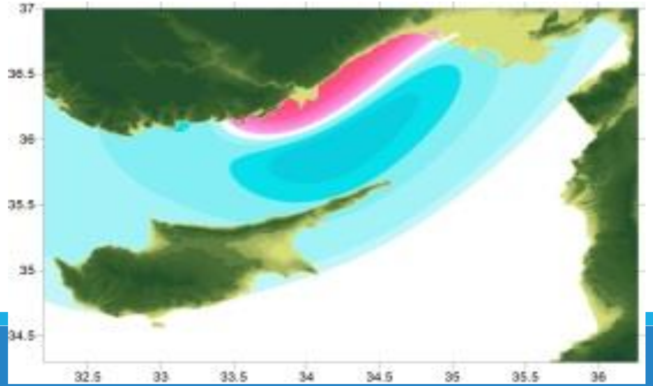


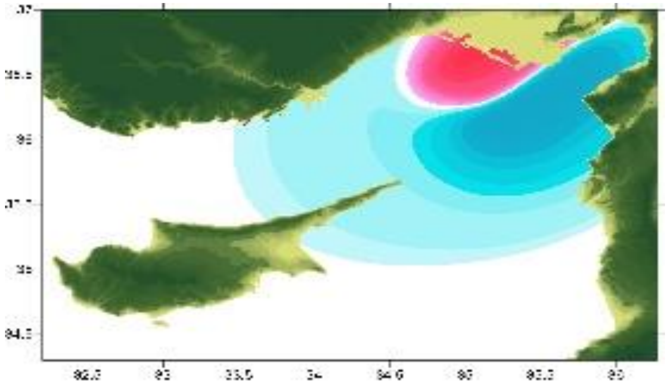


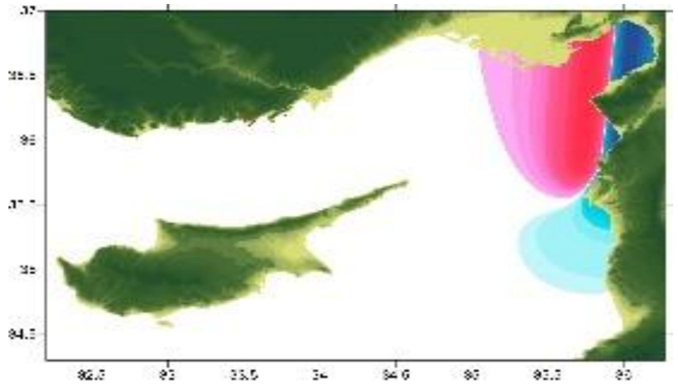






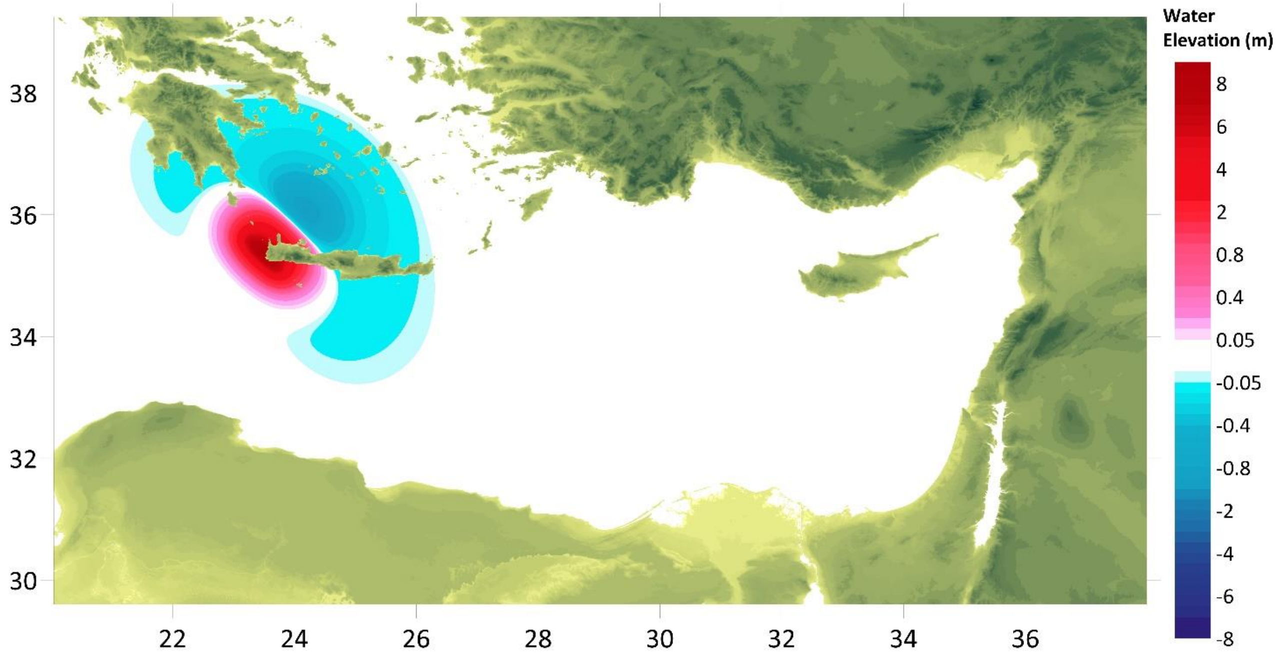


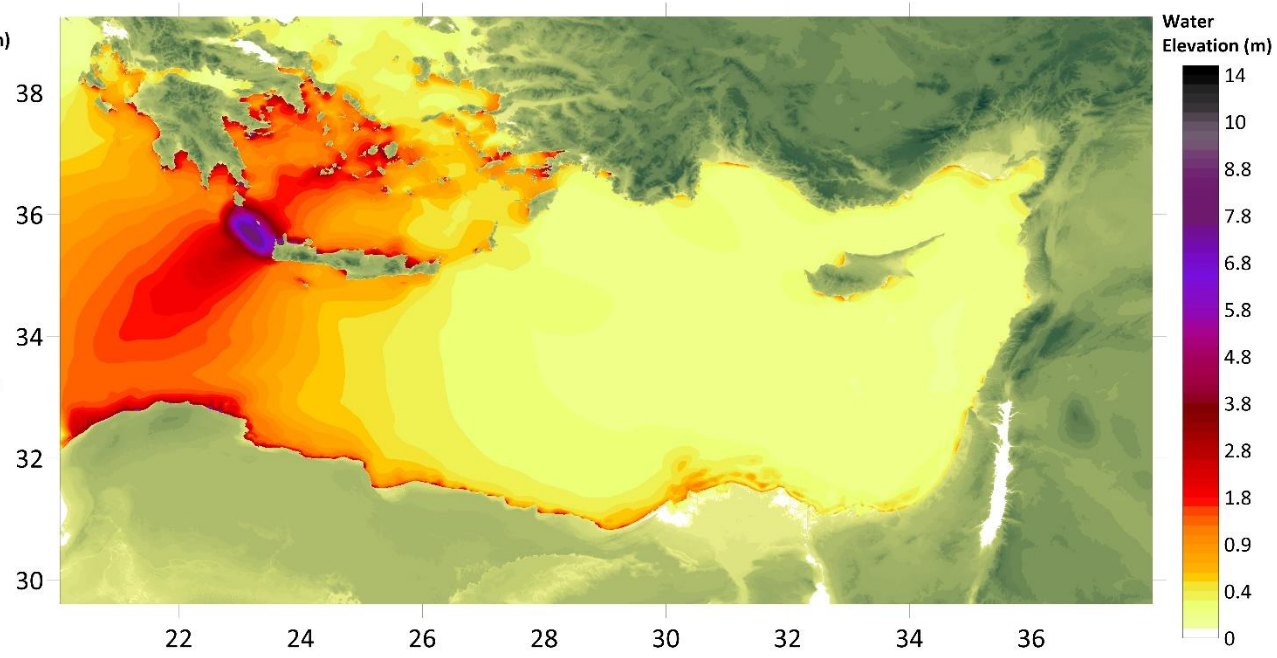




01-365

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
23.45E 35.3N	100	315	90	25	30	90	20	9.07	8.2	-0.9

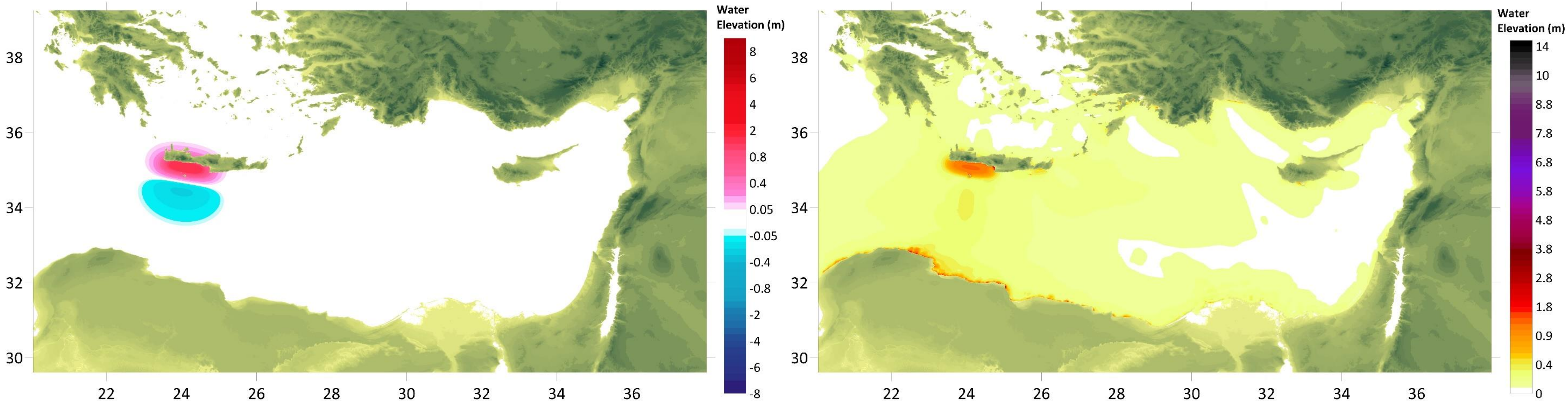




Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

02-Z13-2

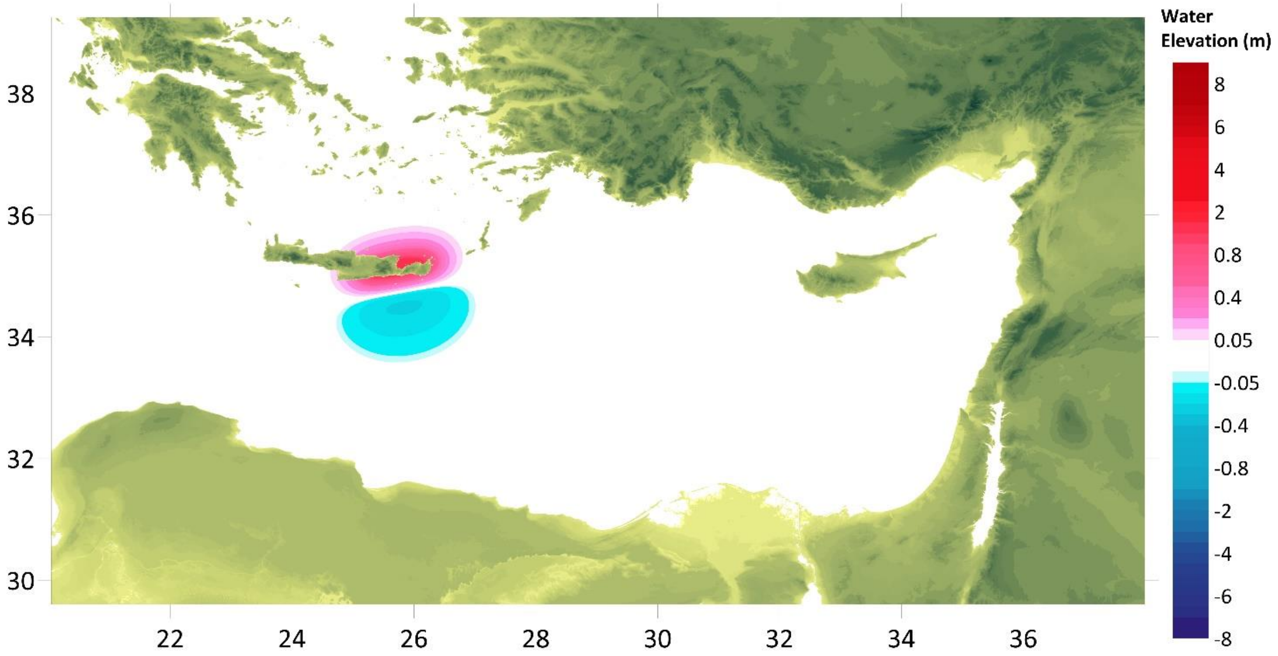
Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
23.5E 35.2N	140	100	35	40	30	90	6	1.48	1.3	-0.2

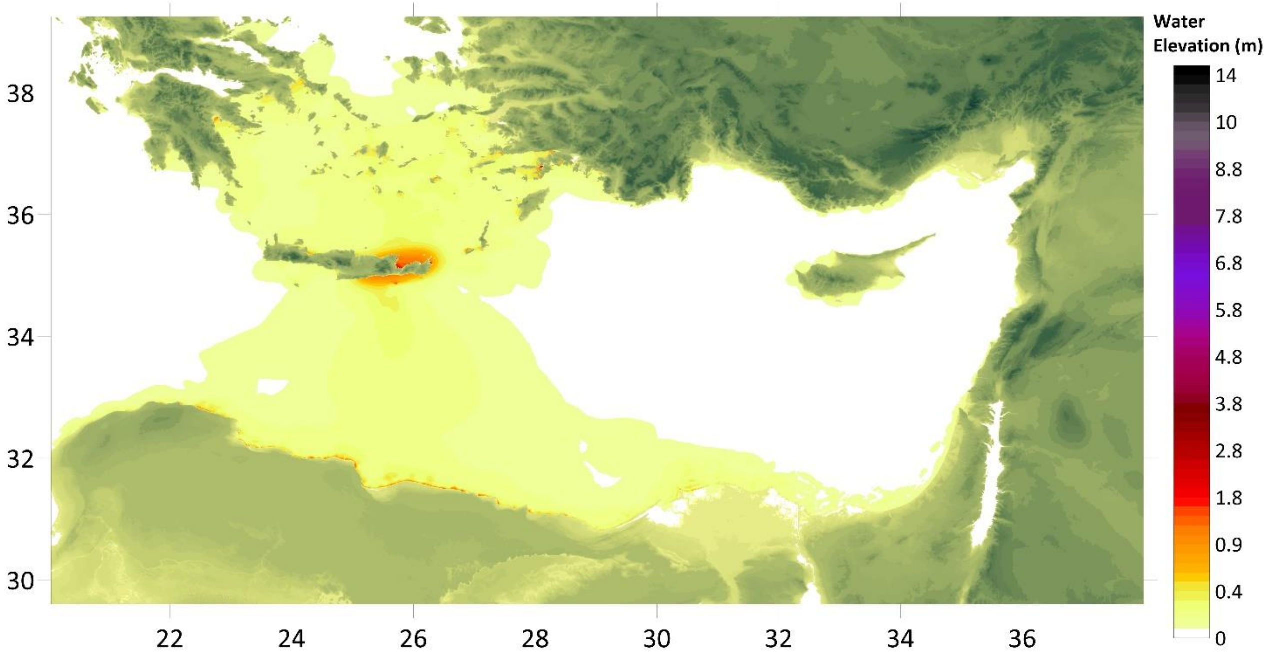


Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

03-Z13-1

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
25.1E 35.05N	140	80	35	40	30	90	6	1.48	1.3	-0.2

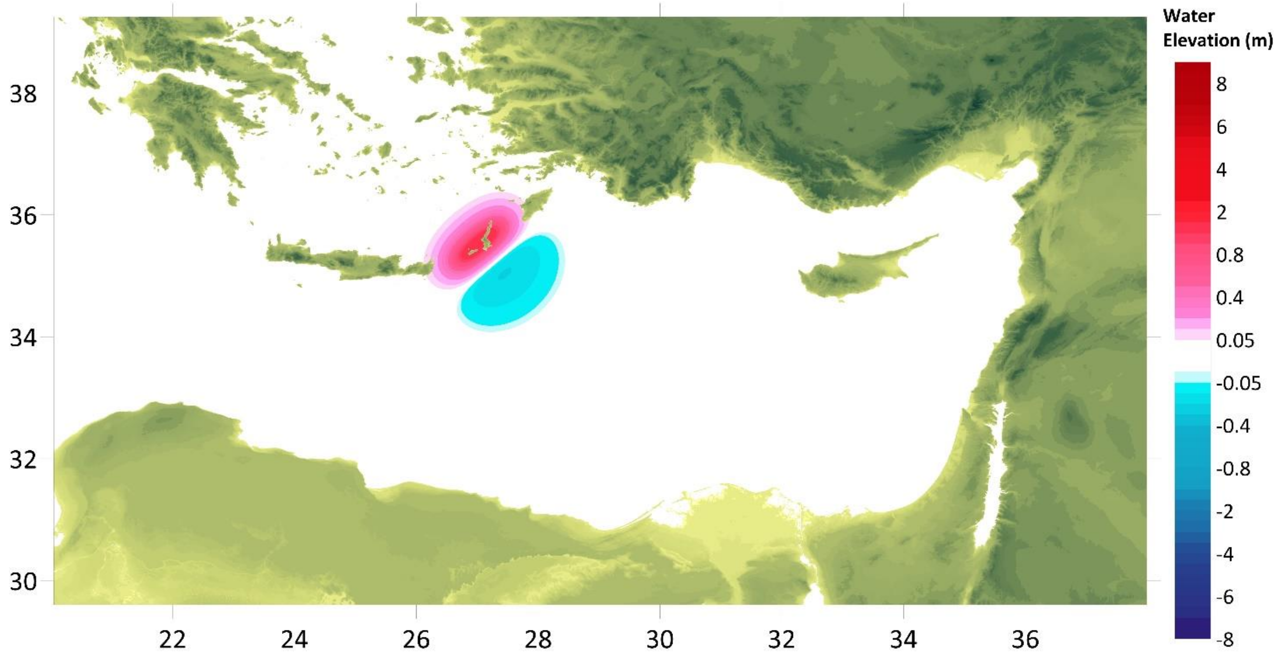


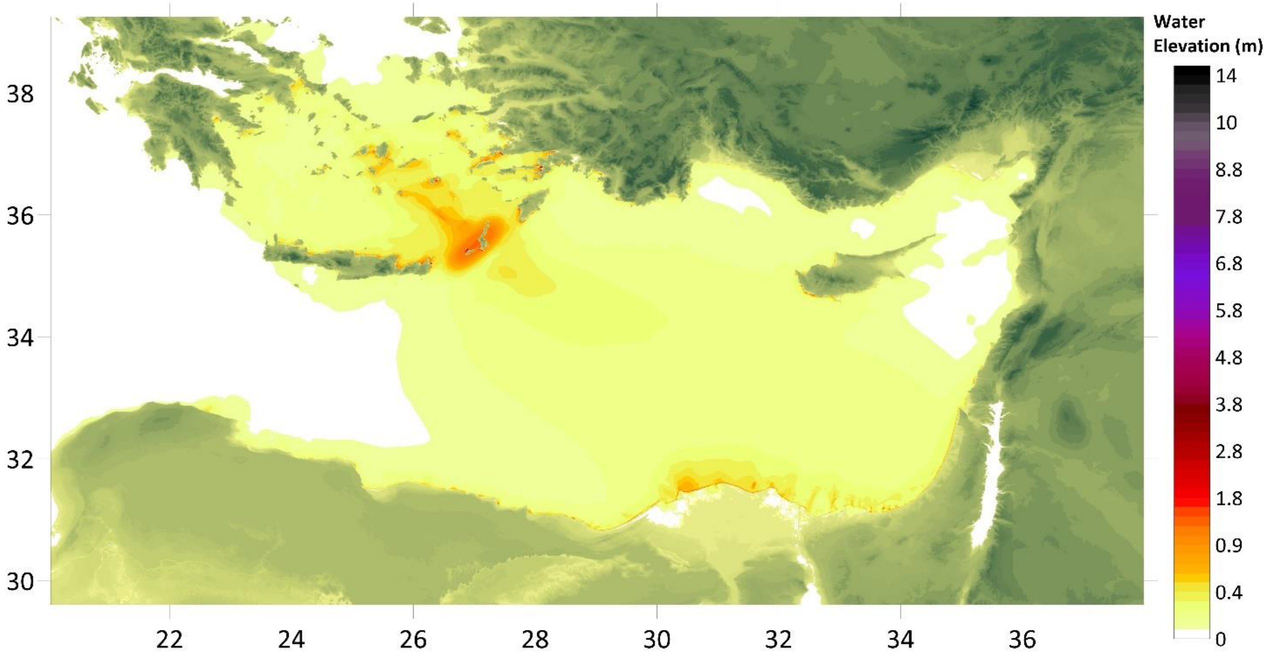


Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

04-Z26-1

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
26.6E 35.2N	120	50	35	40	30	90	6	1.43	1.3	-0.2

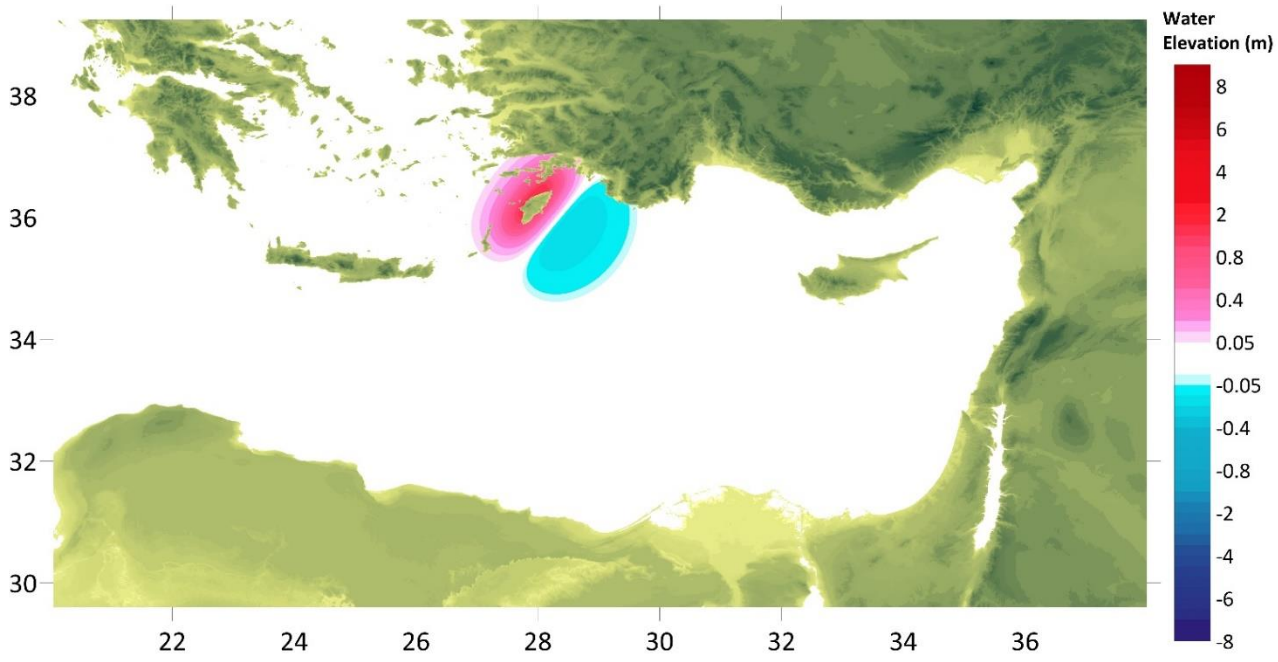


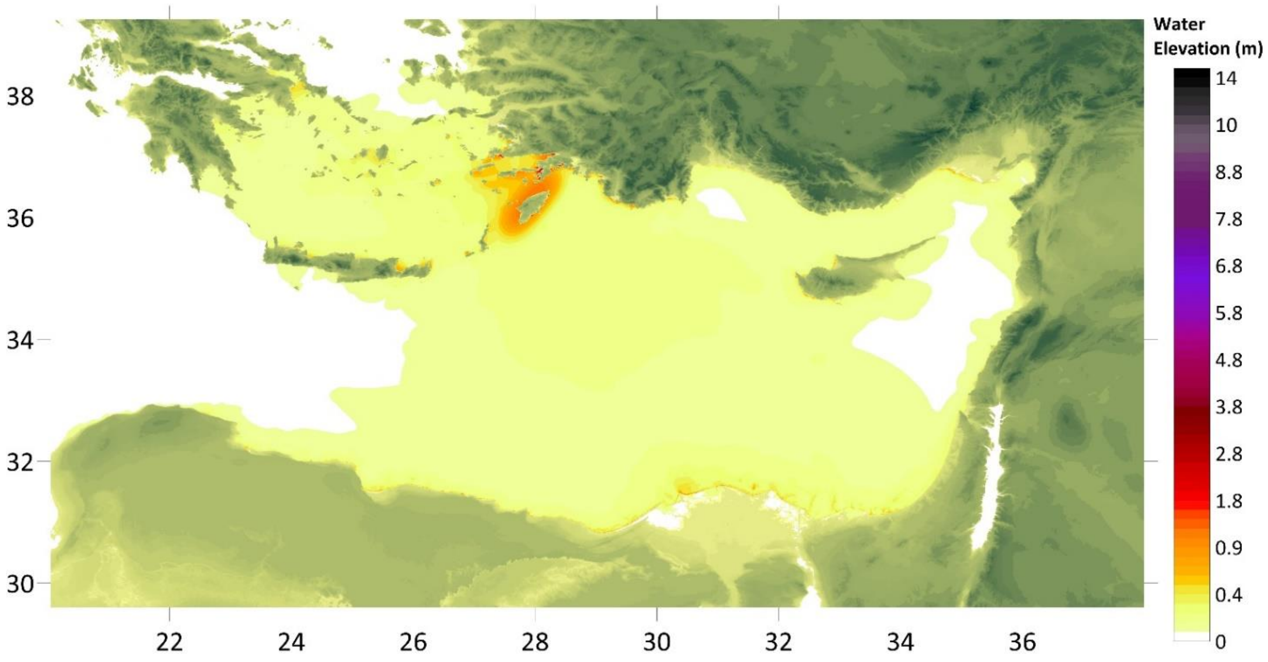


Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

05

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
27.5E 35.8N	140	40	40	50	30	90	6	1.31	1.2	-0.2

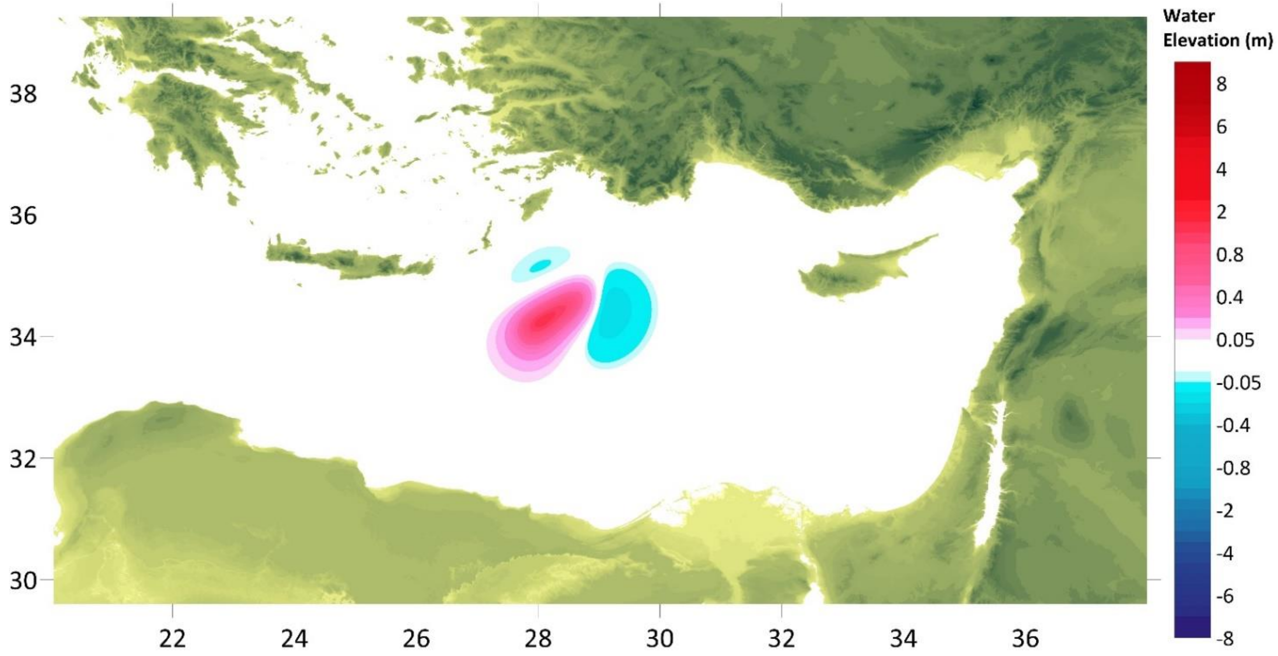


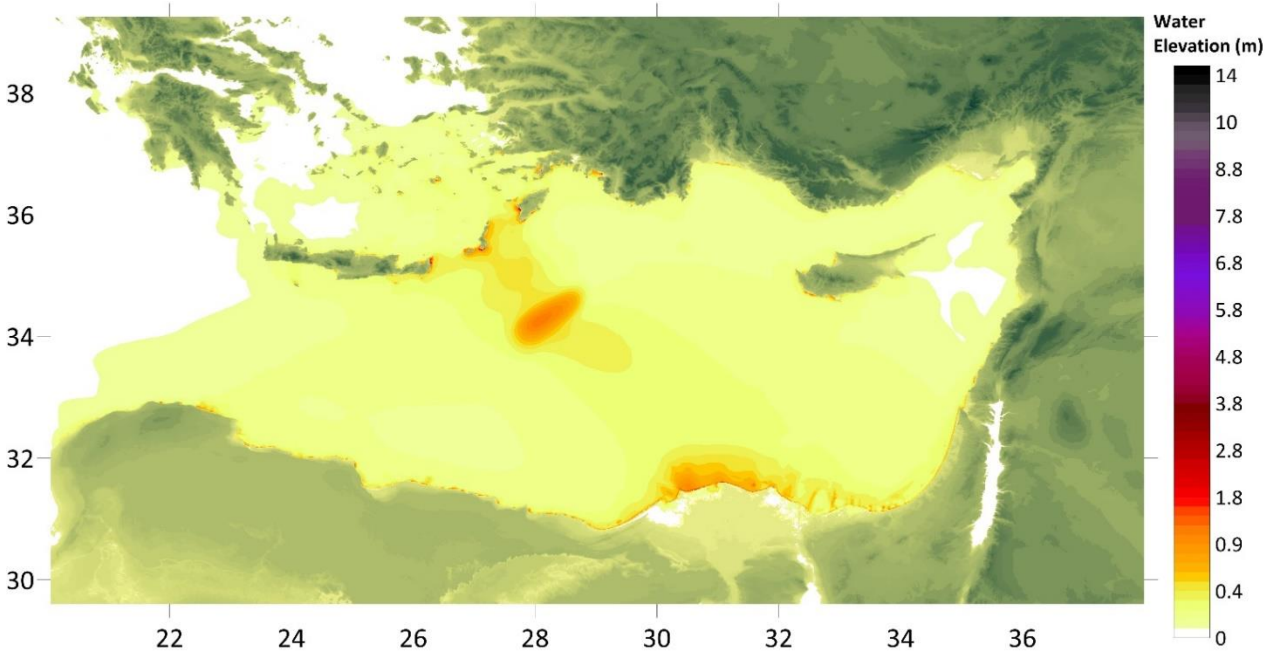


Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

06

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
27.78E 34.2N	136	60	40	40	45	45	6	1.20	1.1	-0.2

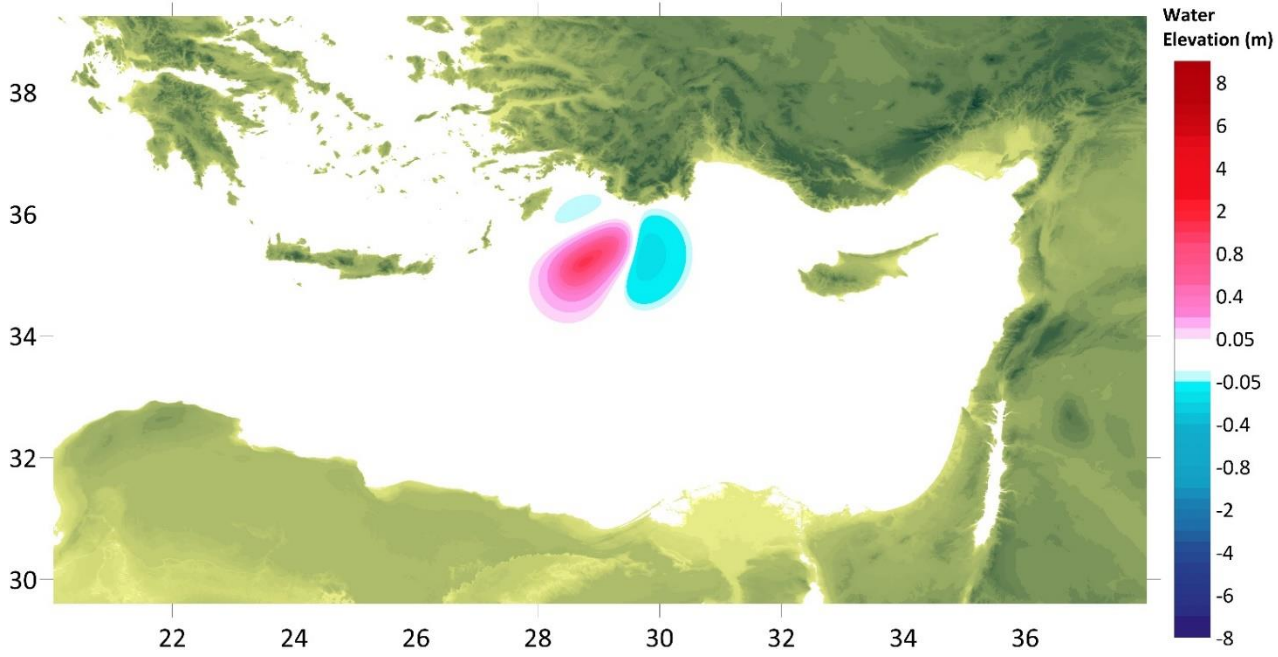


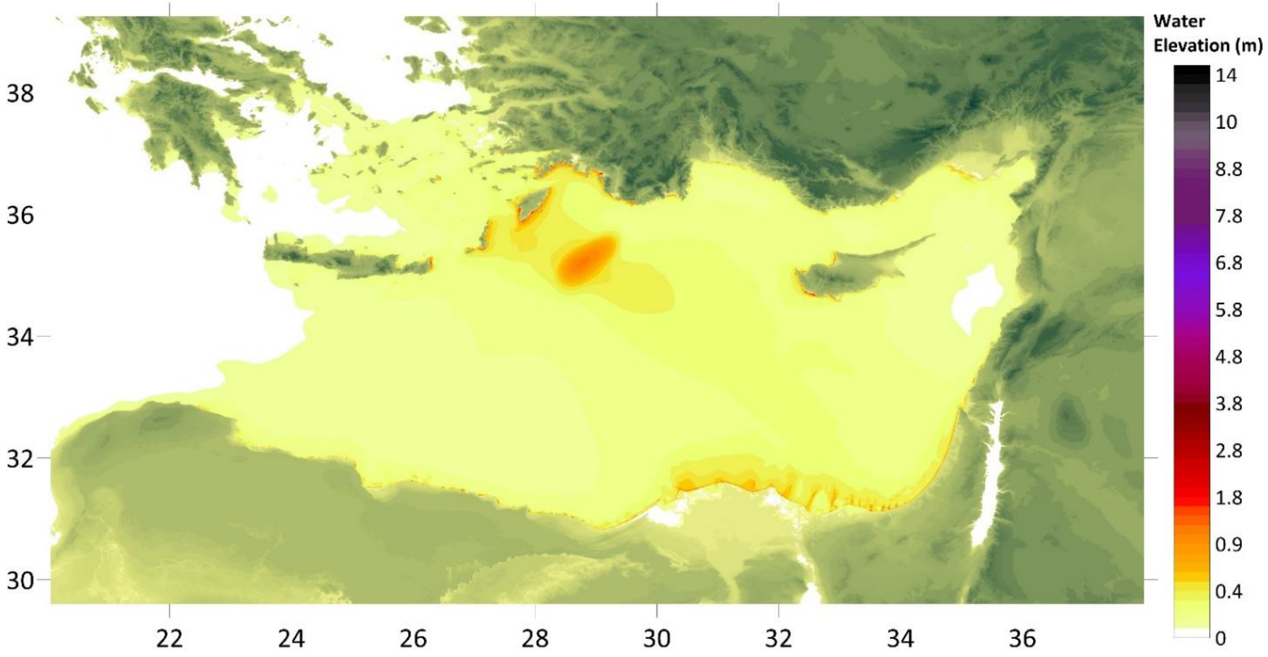


Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

07

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
28.48E 35.16N	121.5	60	40	40	45	45	6	1.18	1.1	-0.2

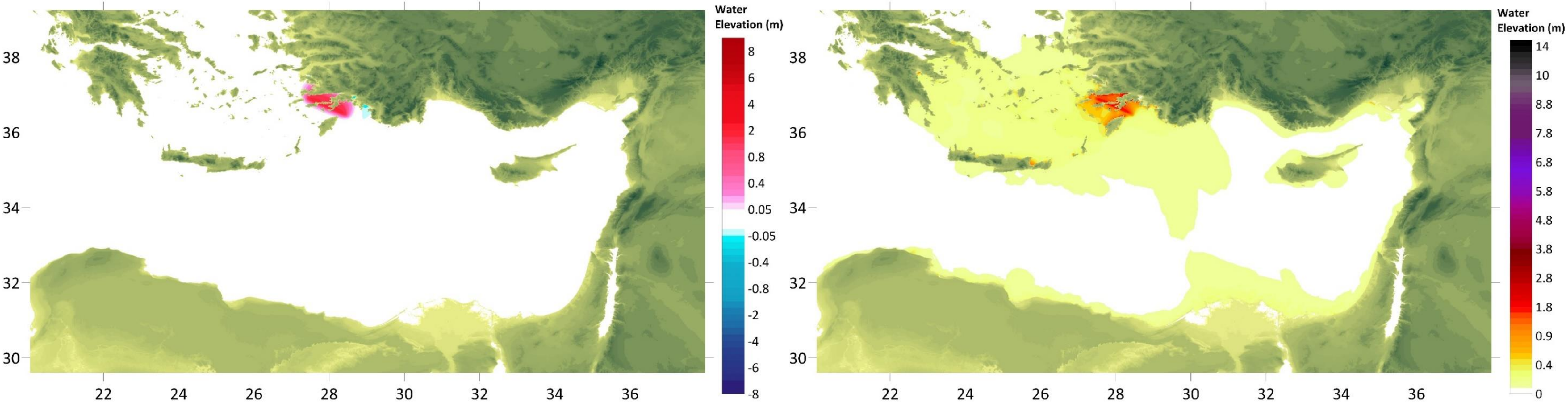




Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

08

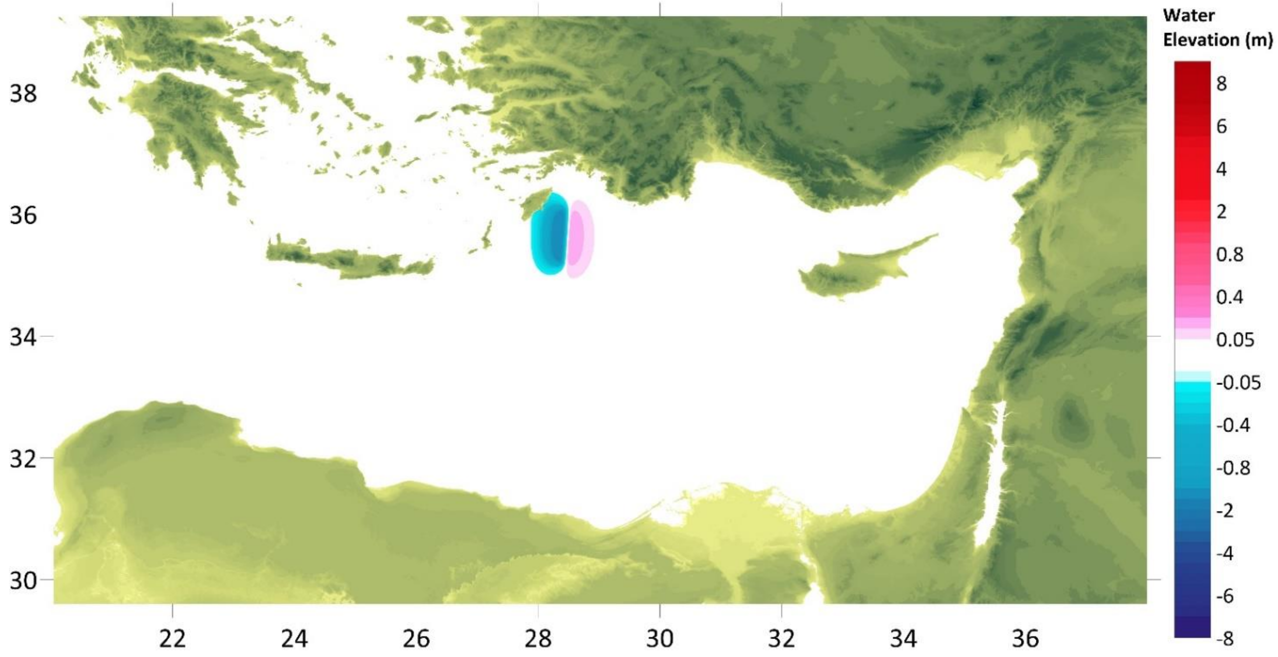
Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
28.462E 36.447N	126	294	63	7.5	27	99	3.65	1.96	1.9	-0.2

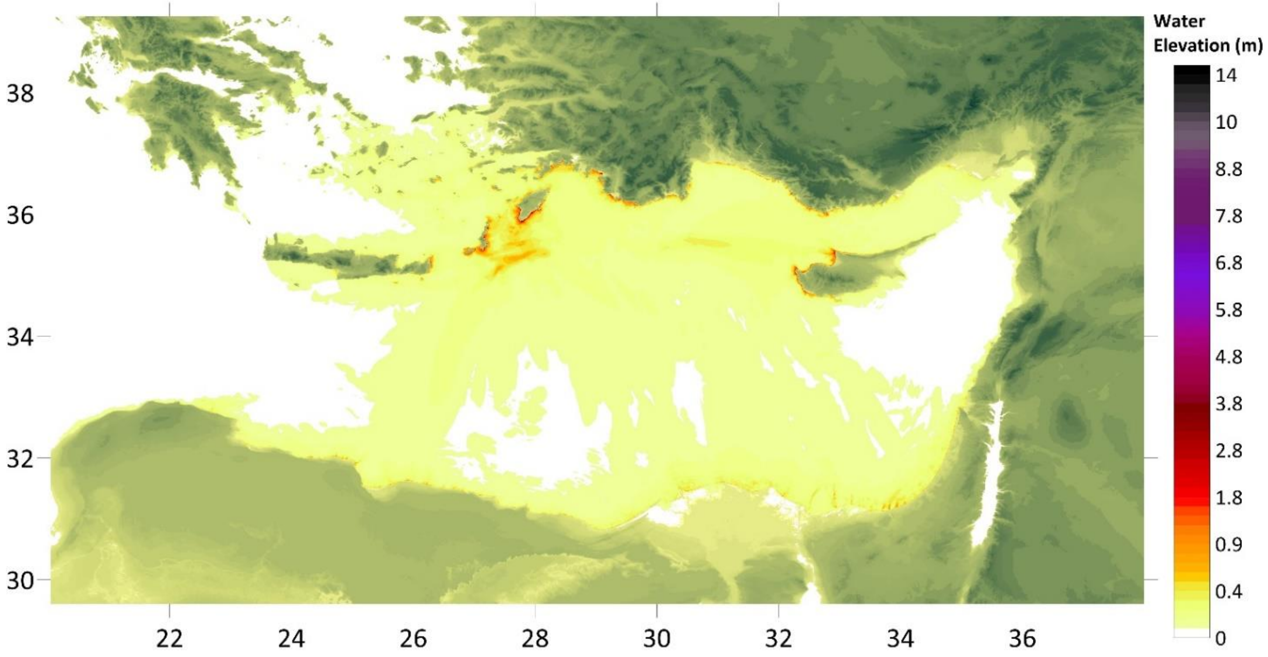


Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

09

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
28.434E 36.077N	100	184	50	7.5	47	262	2.9	1.66	0.2	-1.5

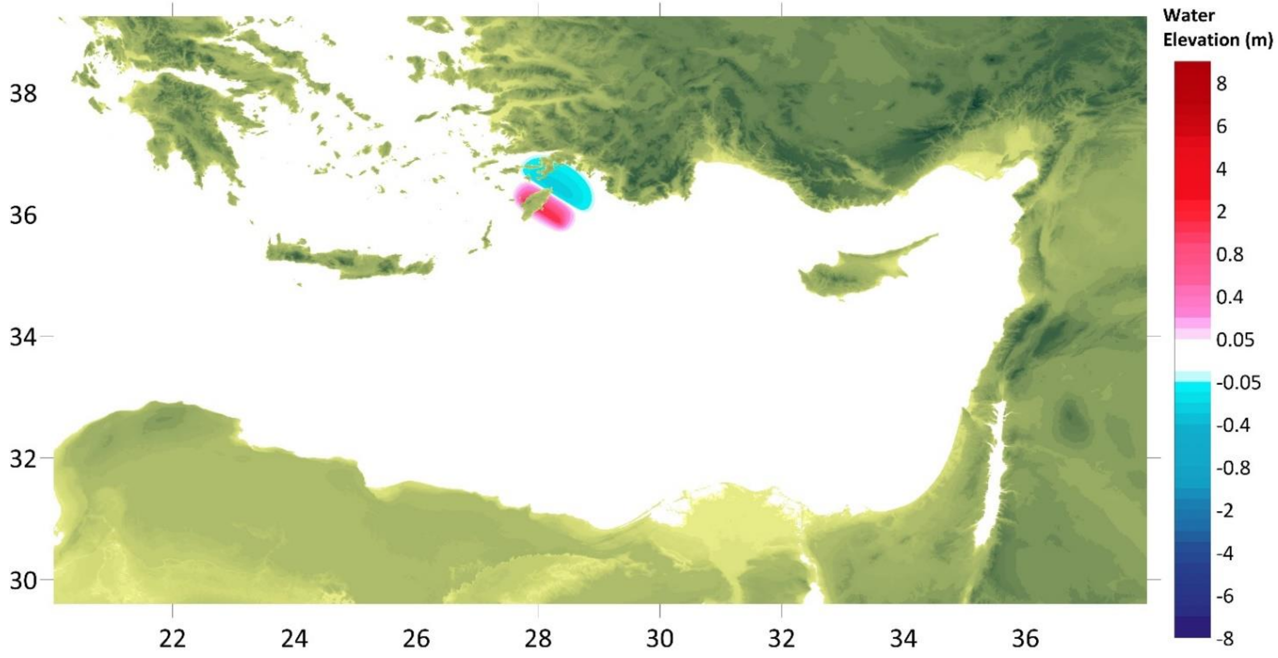


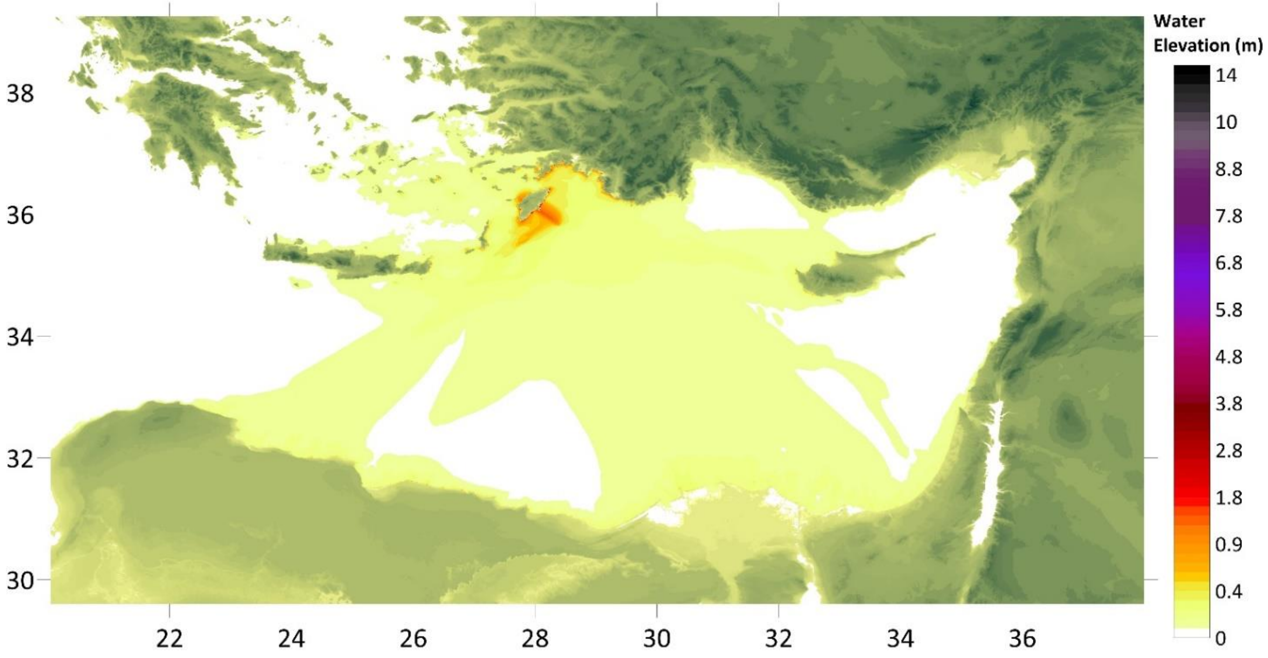


Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

10

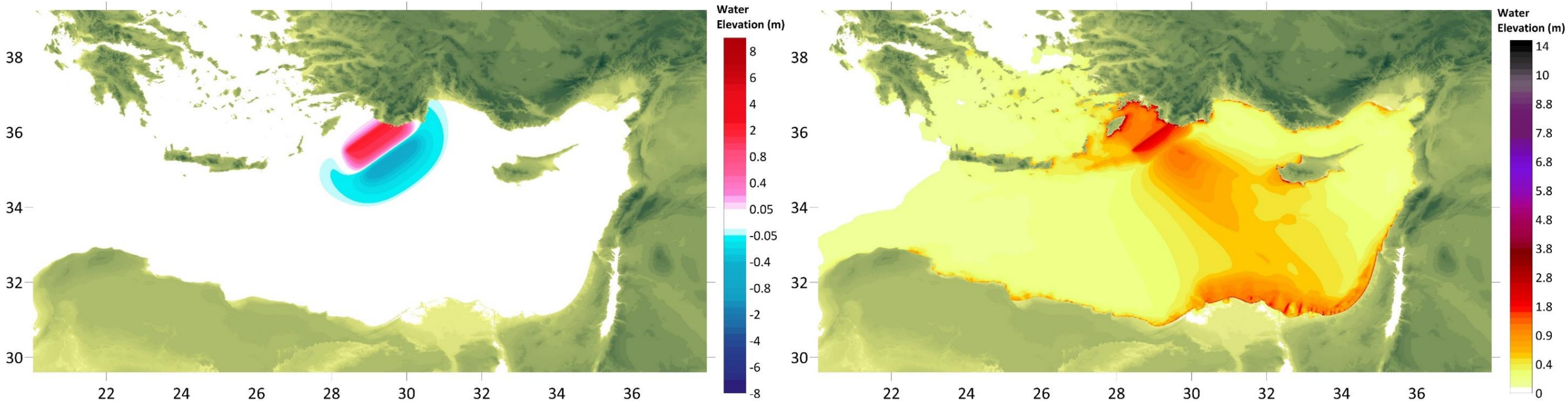
Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
28.393E 35.821N	91	303	45	7.5	25	90	2.7	1.54	1.3	-0.3





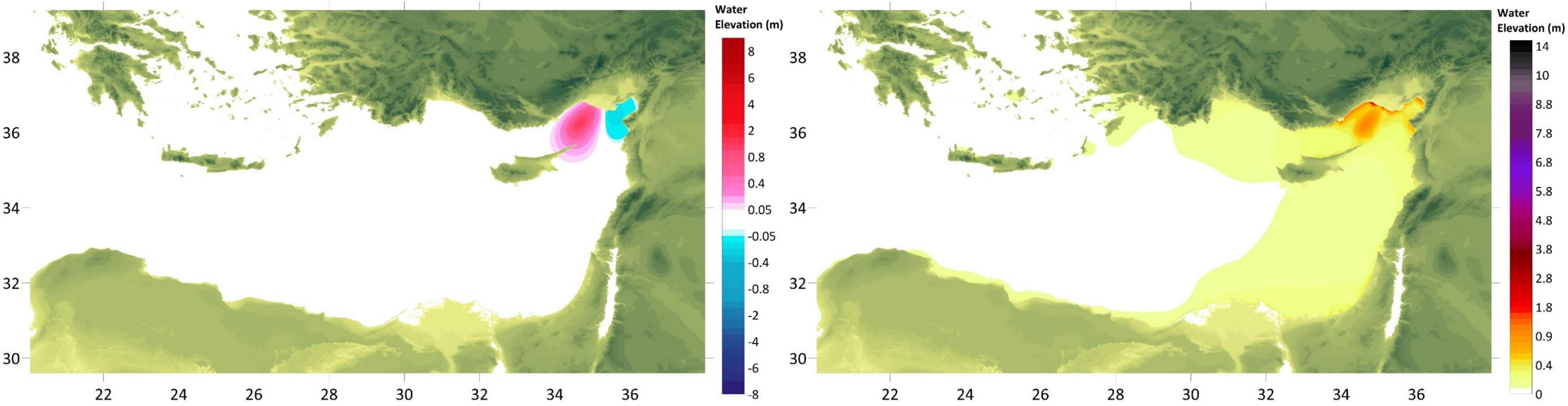
Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
28.4E 35.5N	190	55	90	7.5	20	90	5	3.06	2.4	-0.7



Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

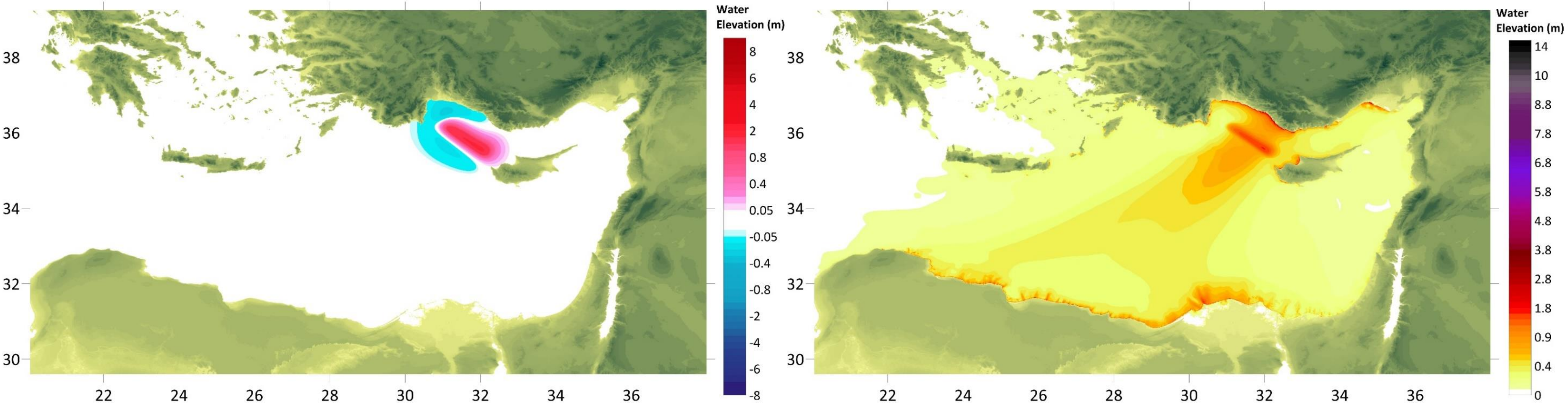
Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
34.41E 36.13N	106	45	40	40	45	45	6	1.14	1.0	-0.2



Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

13-Z32

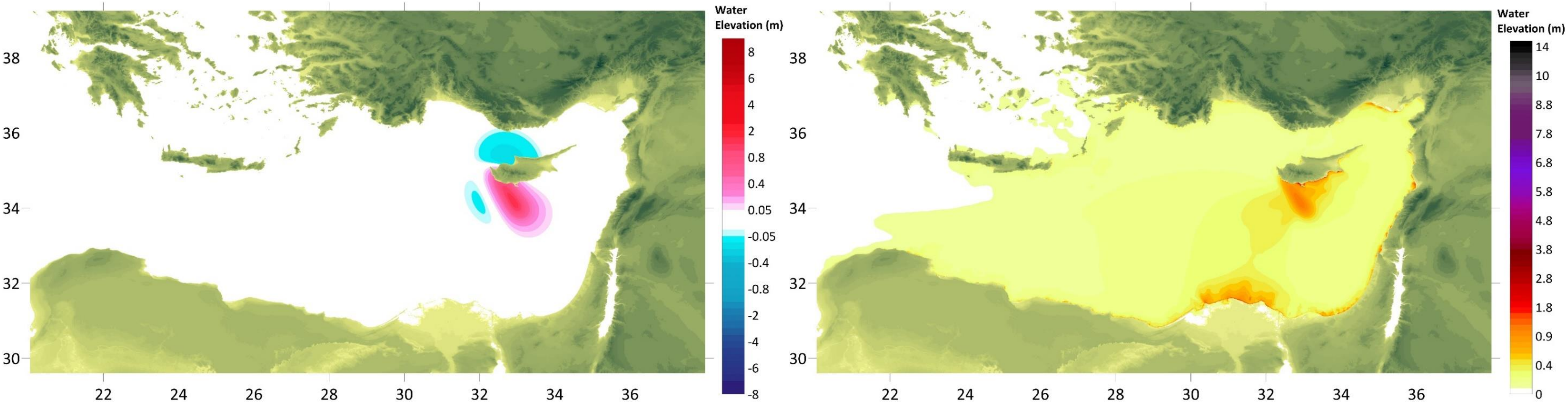
Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
32.1E 35.4N	156	305	40	20	45	45	6	1.84	1.6	-0.2



Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

14-Z30

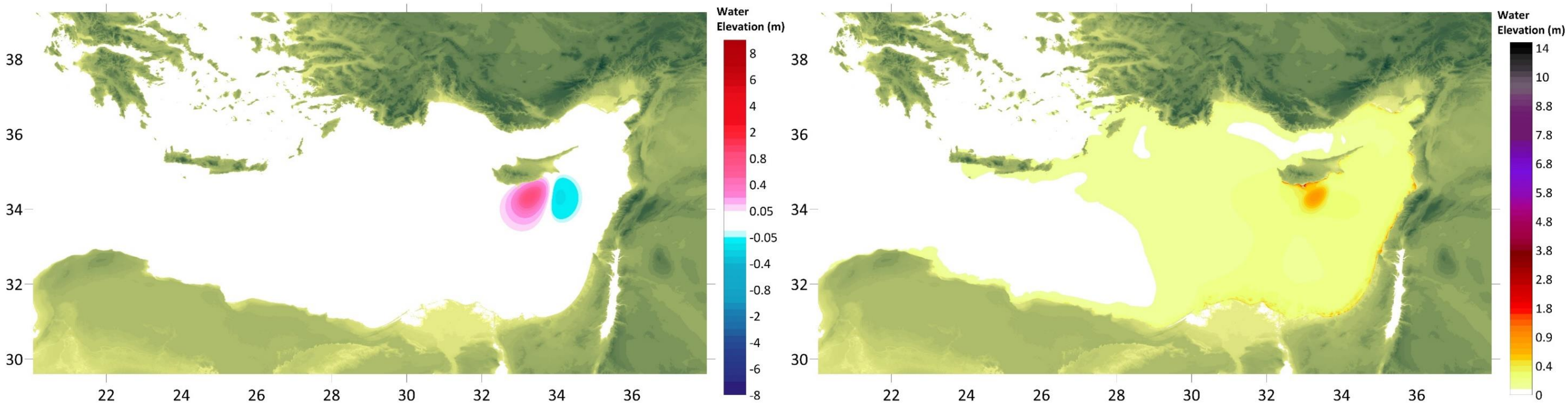
Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
32.98E 33.83N	149	330	40	40	45	45	6	1.21	1.1	-0.2



Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

15-Z31-2

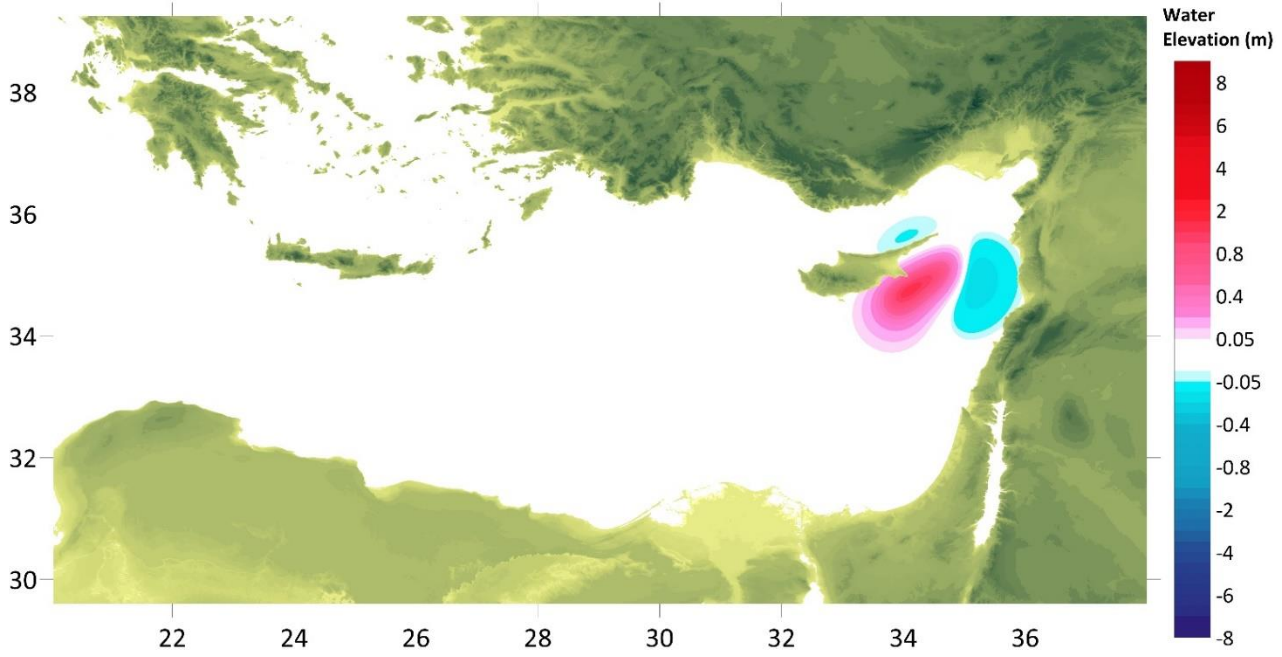
Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
33.09E 34.33N	73	60	40	40	45	45	6	1.00	0.9	-0.1

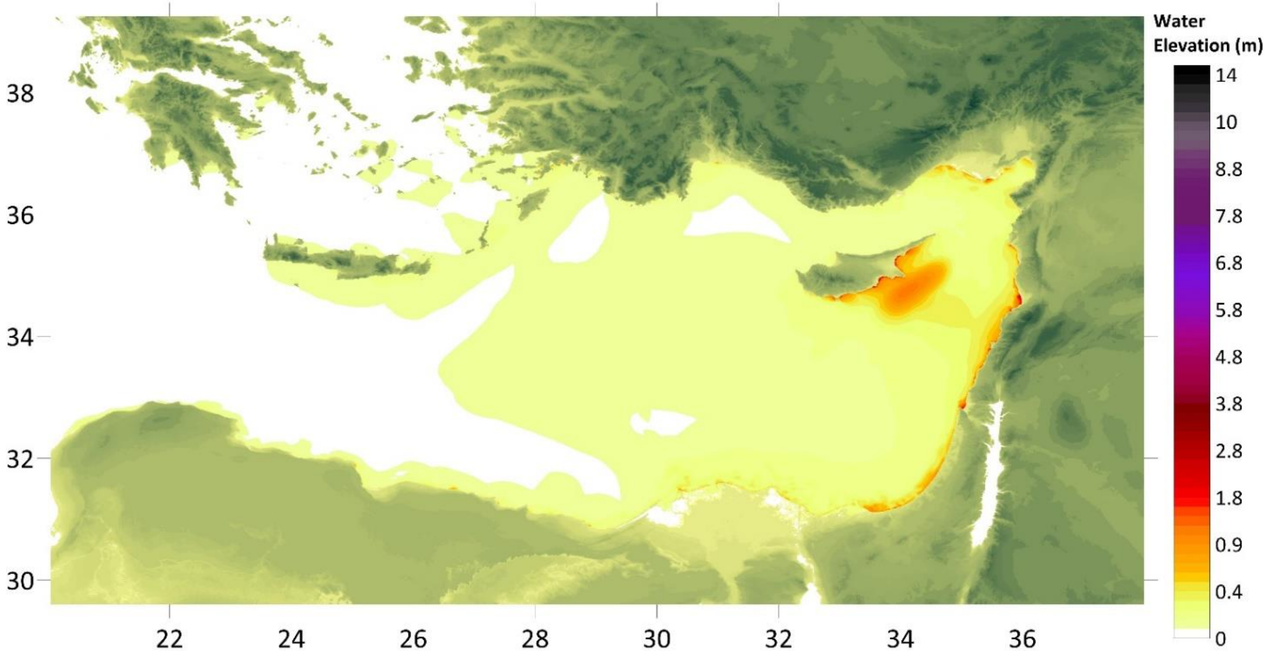


Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

16-Z31-1

Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
33.79E 34.68N	137	60	40	40	45	45	6	1.20	1.1	-0.2

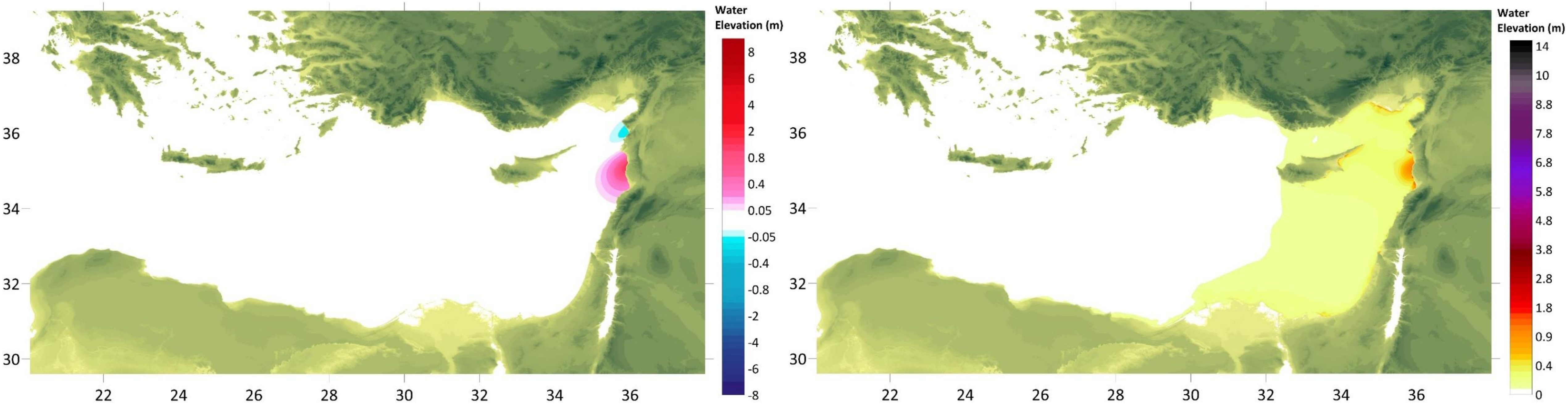




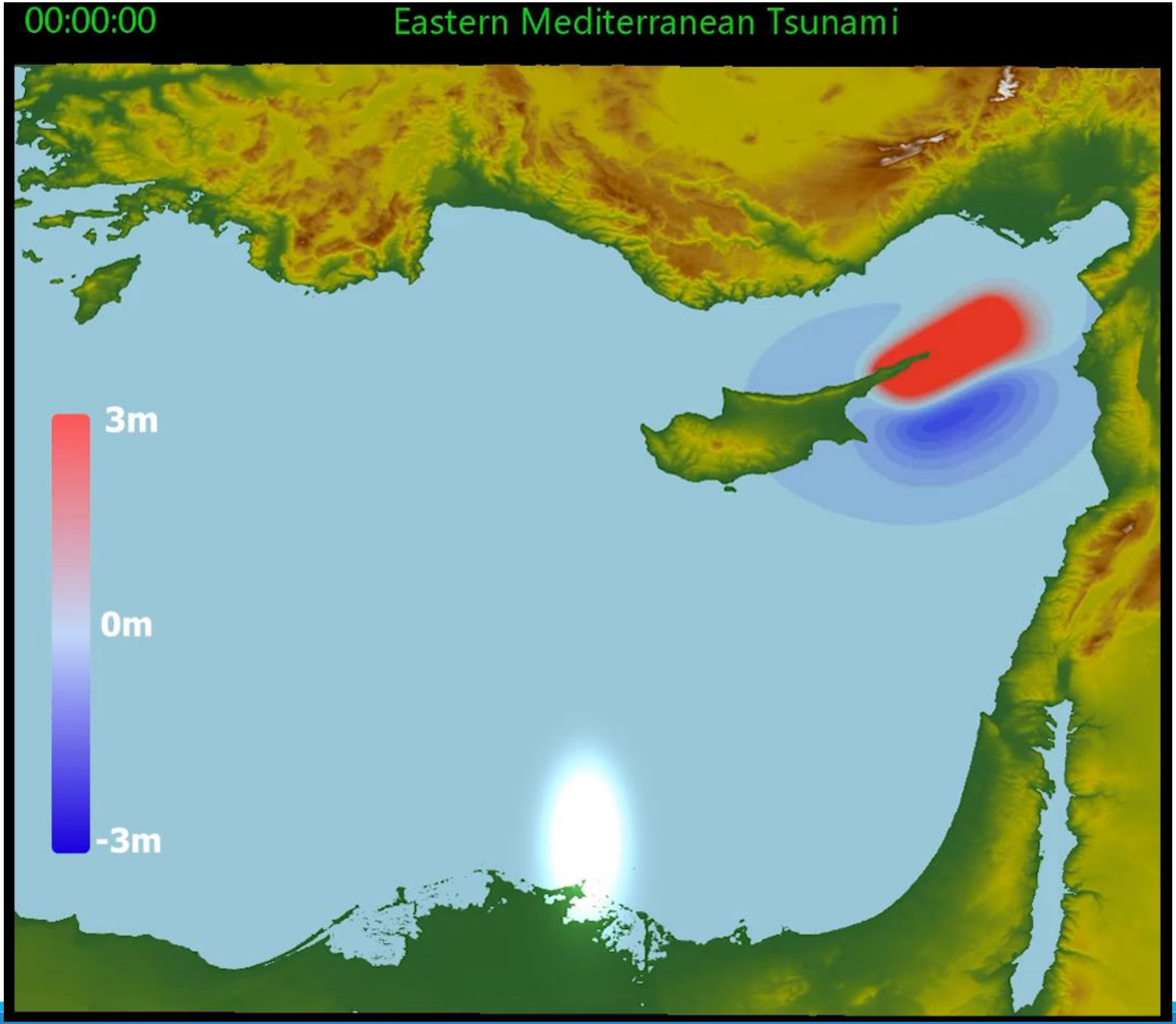
Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation

17-Z41

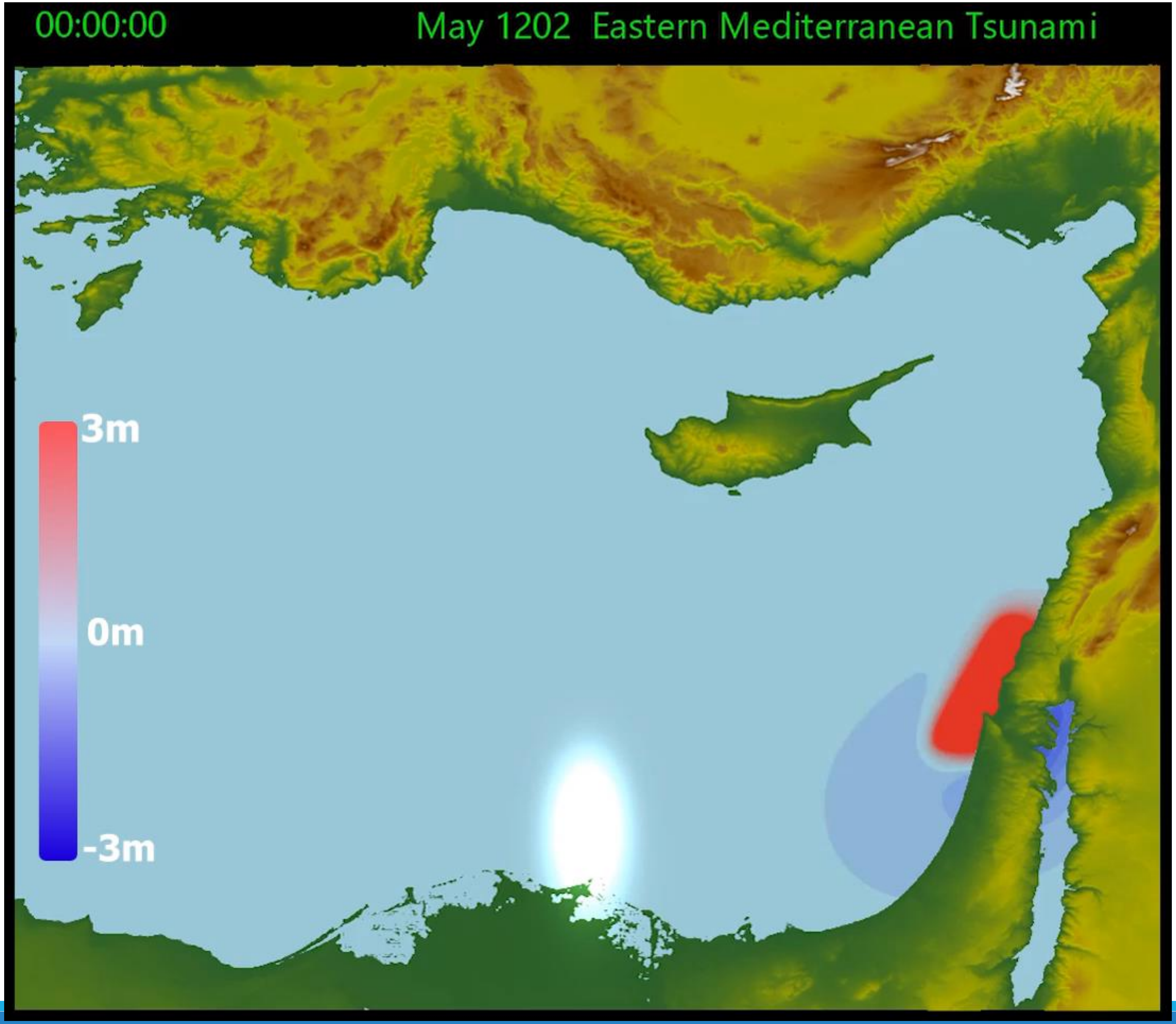
Epicenter	Lenght of Fault (km)	Strike angle (° W)	Width of fault (km)	Focal Depth (km)	Dip angle (°)	Slip angle (°)	Displacement (km)	Height of initial wave (m)	Maximum positive amplitude (m)	Minimum negative amplitude (m)
35.7E 35.07N	175	60	40	40	45	45	6	1.06	1.0	-0.1



Tsunami Source & Distribution of Maximum Water Elevations in Eastern Mediterranean After 4-hr Simulation



Example tsunami generation and propagation on Misis Kyrenia Fault



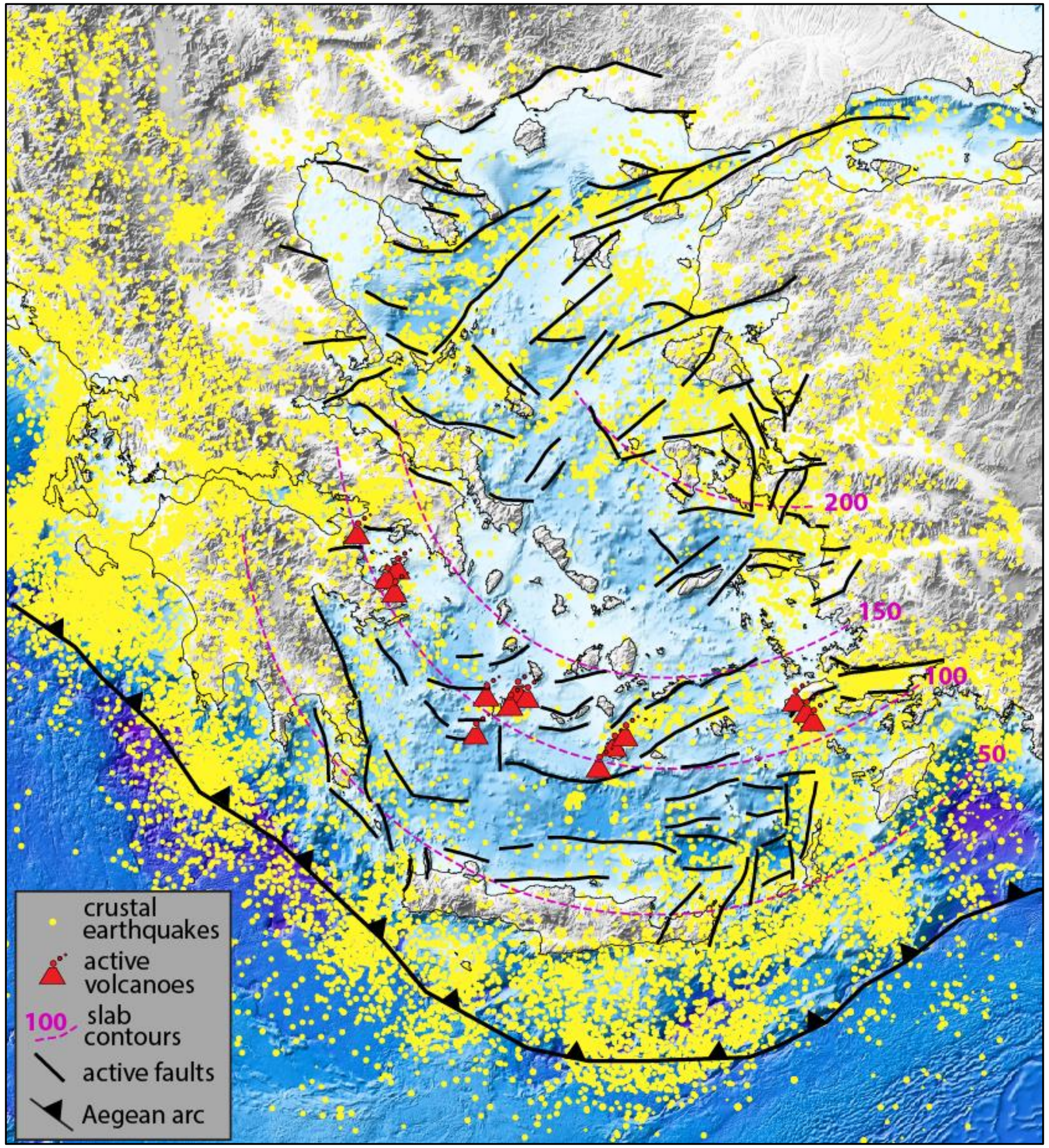
May 1202 Tsunami

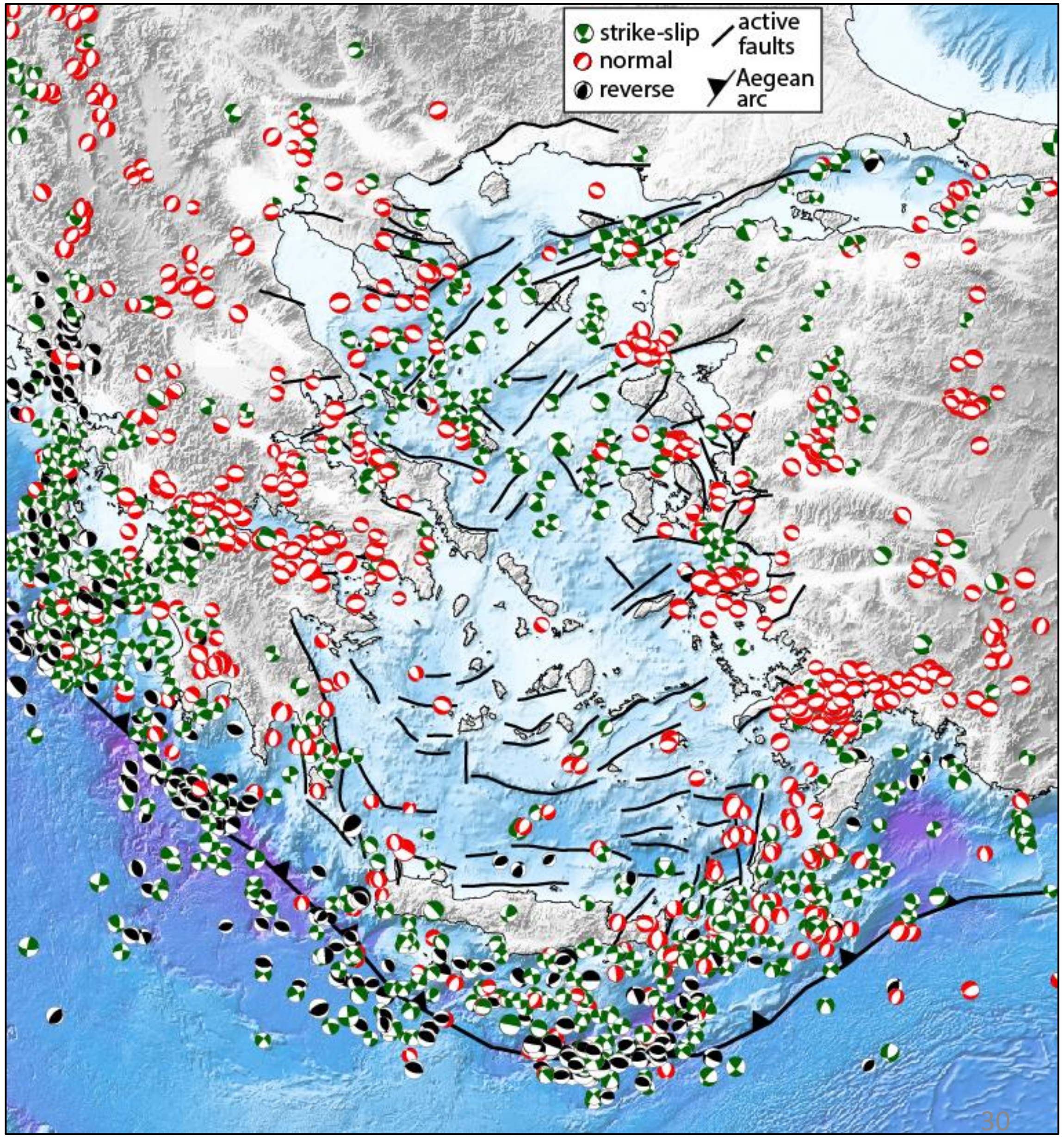
Characteristics of 2025 Aegean Sea Earthquake Swarm & Potential Tsunami Scenarios

Ahmet Cevdet Yalçıner[a], Gözde Güney Doğan[a,b], Setenay Özaslan[a], Bilge Karakütük[a], Arda Özacar[c]

[a] *Middle East Technical University, Civil Engineering Department, Türkiye*
[b] *Delft University of Technology, Hydraulic Engineering Department, Netherlands*
[c] *Middle East Technical University, Geological Engineering Department, Türkiye*

Active Tectonic Setting of Aegean Region





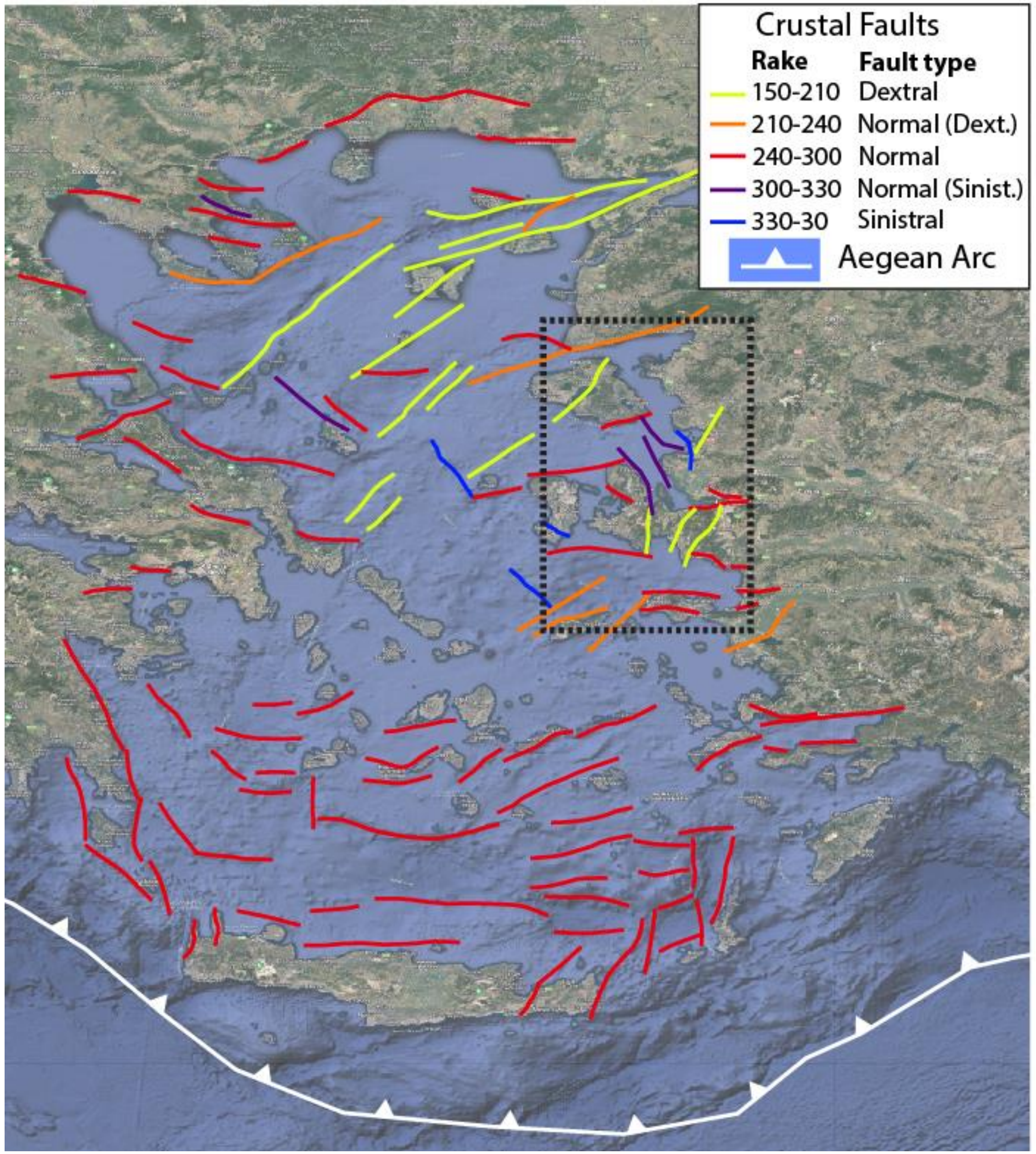
Probabilistic Tsunami Analysis of Aegean Region: Fault Sources

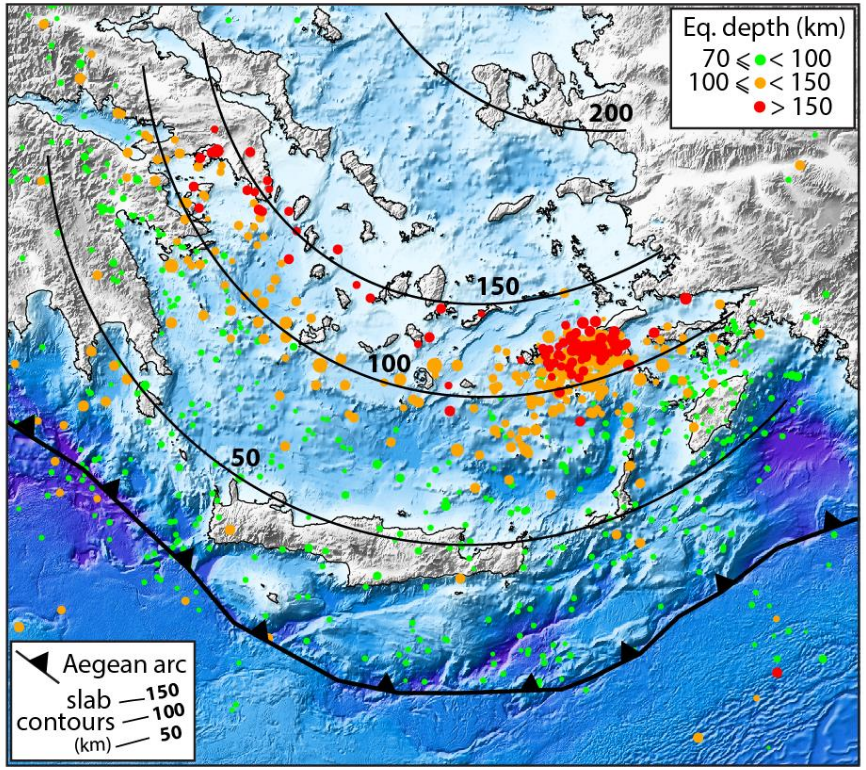
TÜBİTAK project (2021-2025) No: 121M750

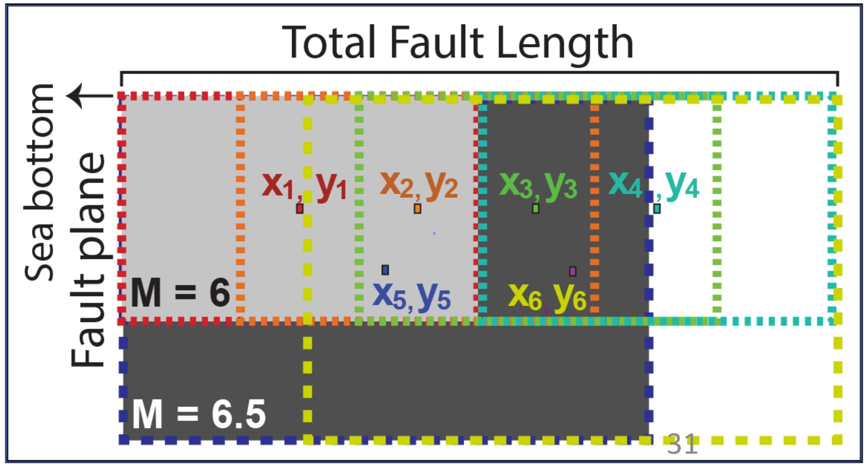
Tsunamigenic faults in Aegean are compiled from Basilli et al. (2013)

Tsunami scenarios for M ≥ 6 events on all tsunamigenic faults with up to 50% spatial overlap are generated (> 10K scenarios)

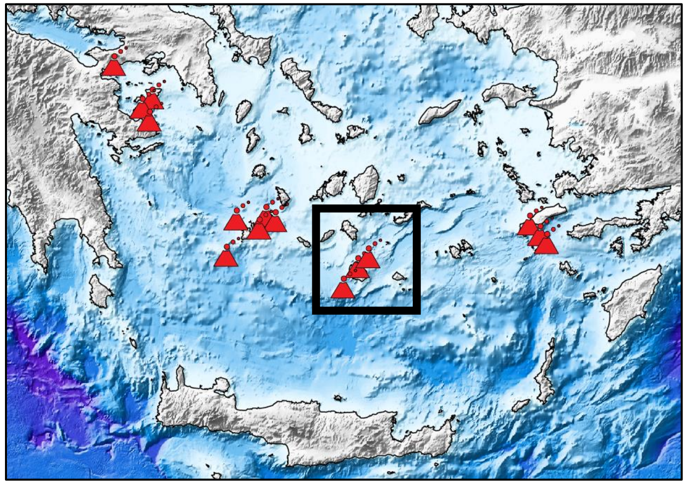
(Note that for subduction: M ≥ 6.5)





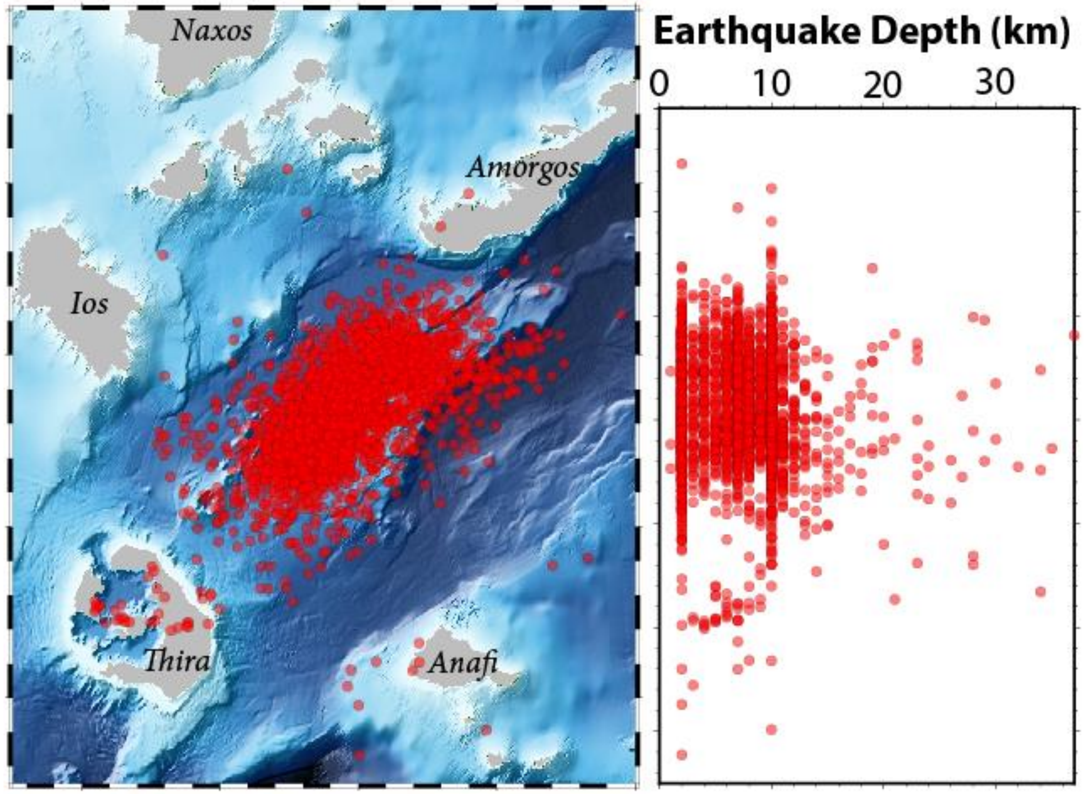


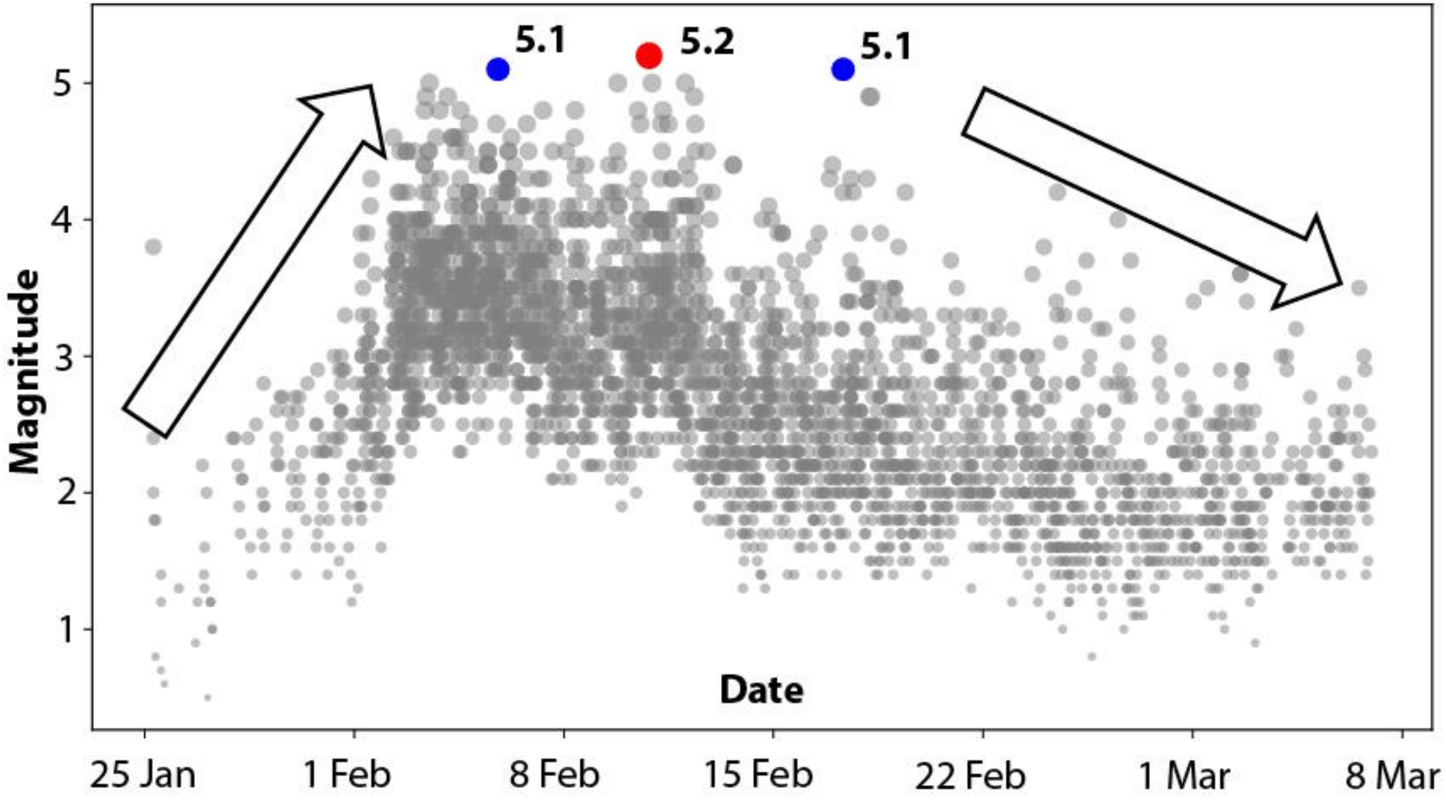
Early 2025 Aegean Earthquake Storm



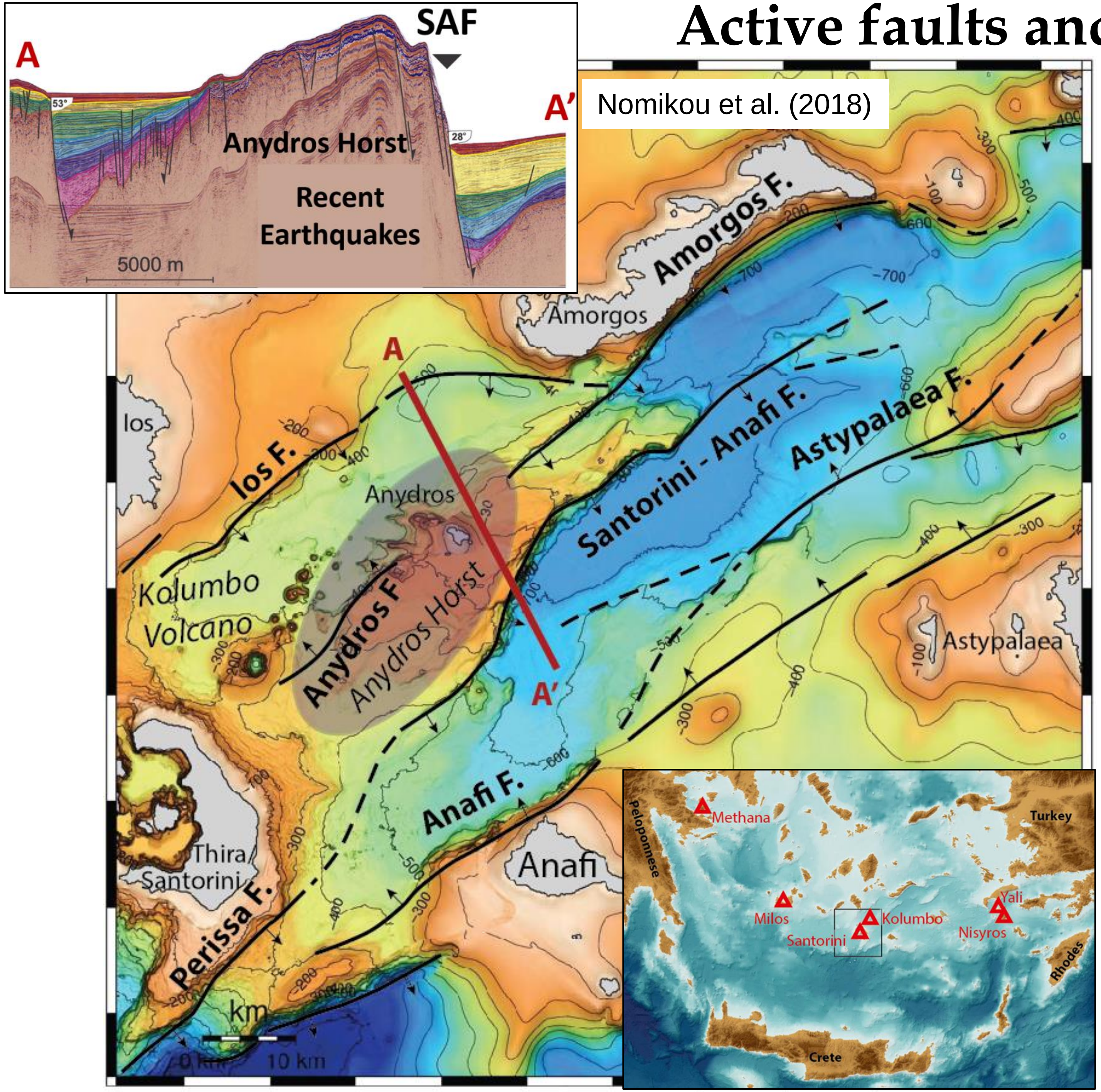
Frequency and magnitudes of earthquakes rapidly increased and produced several M>5 earthquakes.

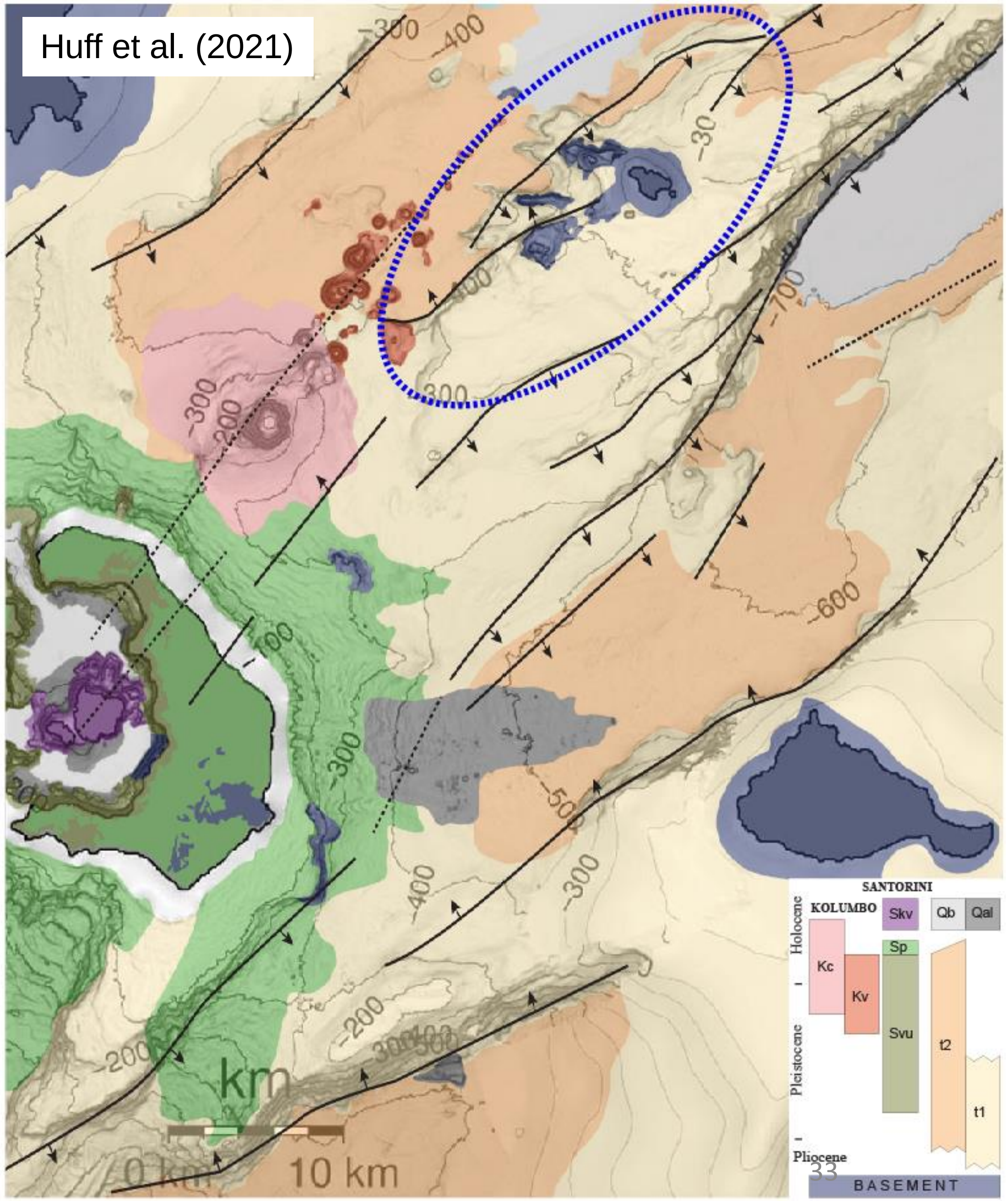
After several weeks, earthquake magnitudes begun to decrease.



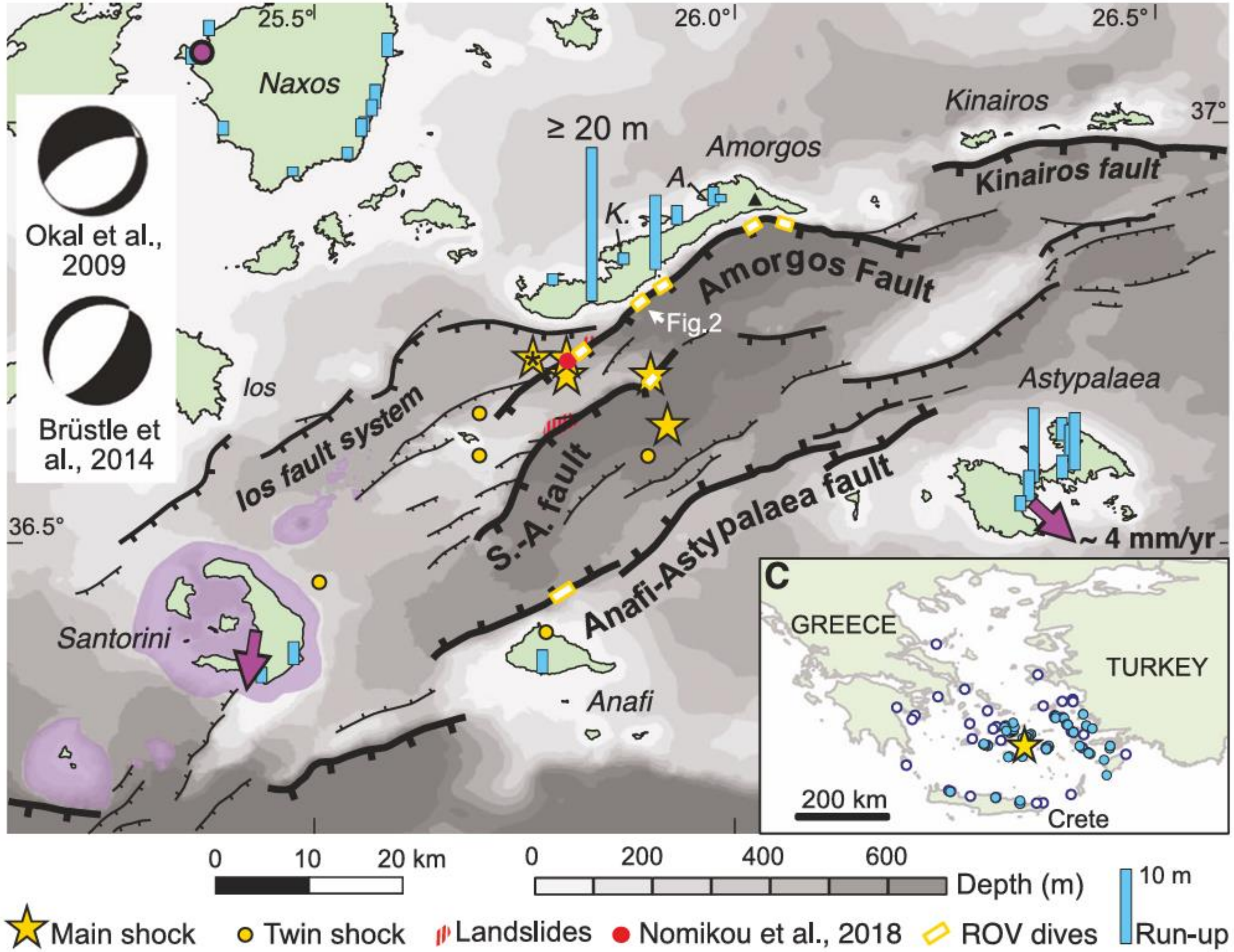


Active faults and volcanoes in the region

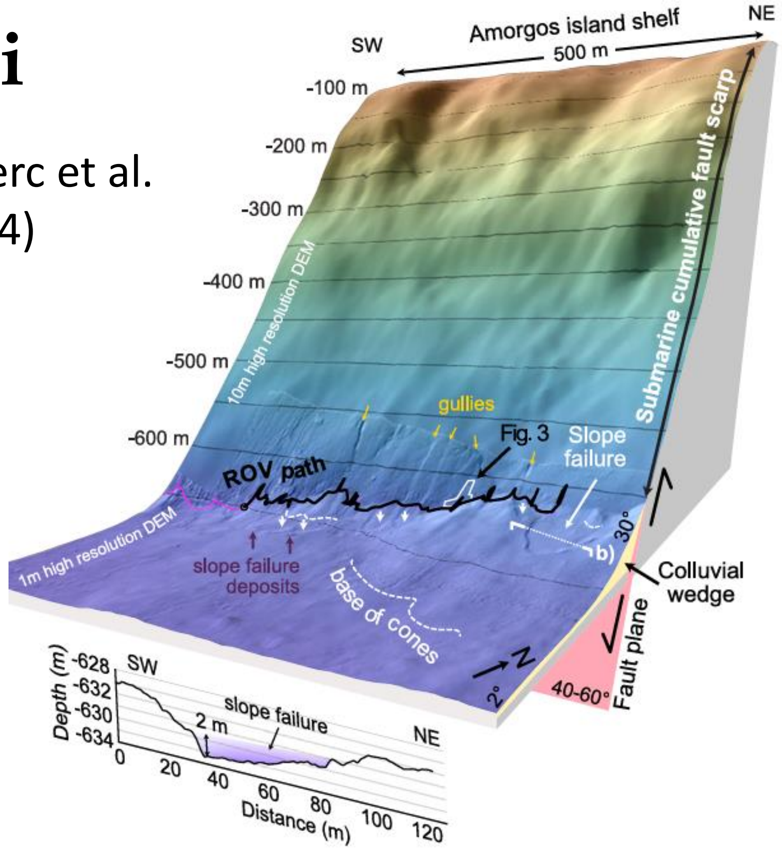


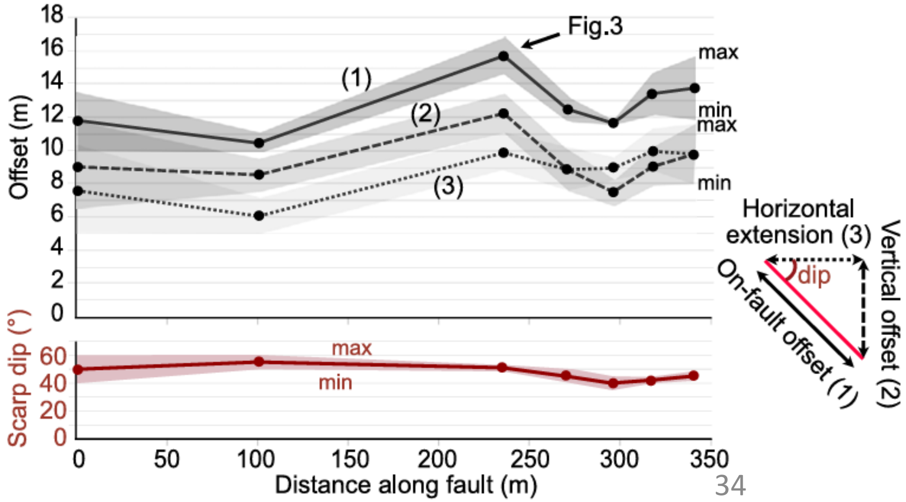


1956 Amorgos Earthquake & Observed Tsunami

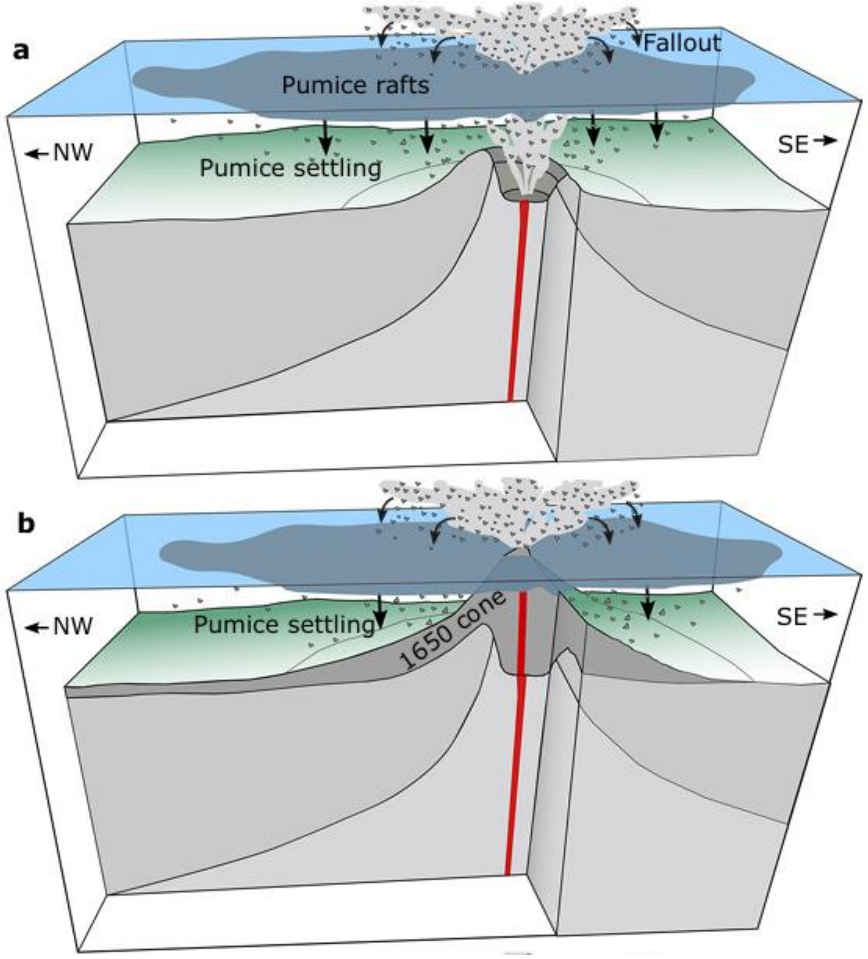


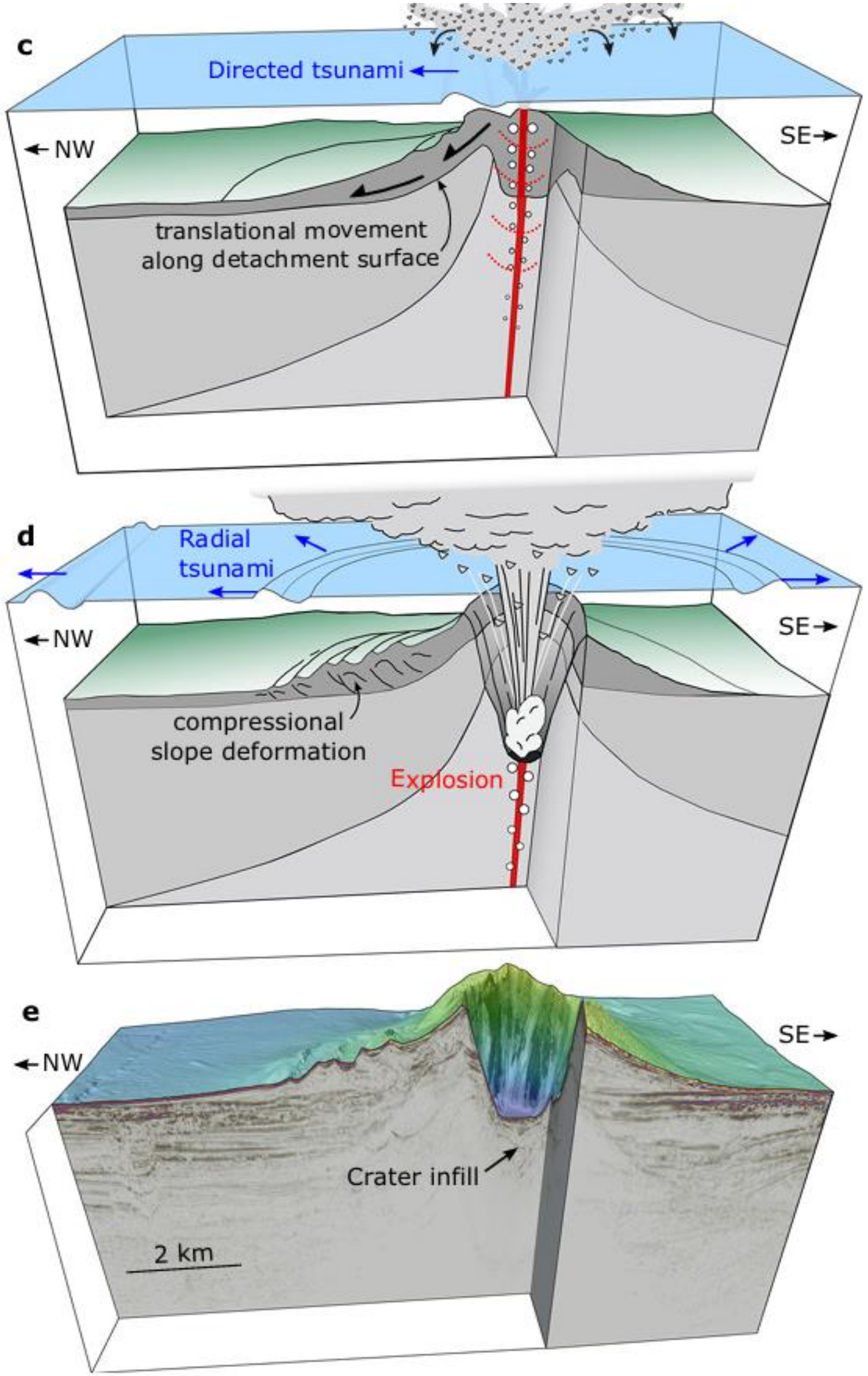
Leclerc et al. (2024)

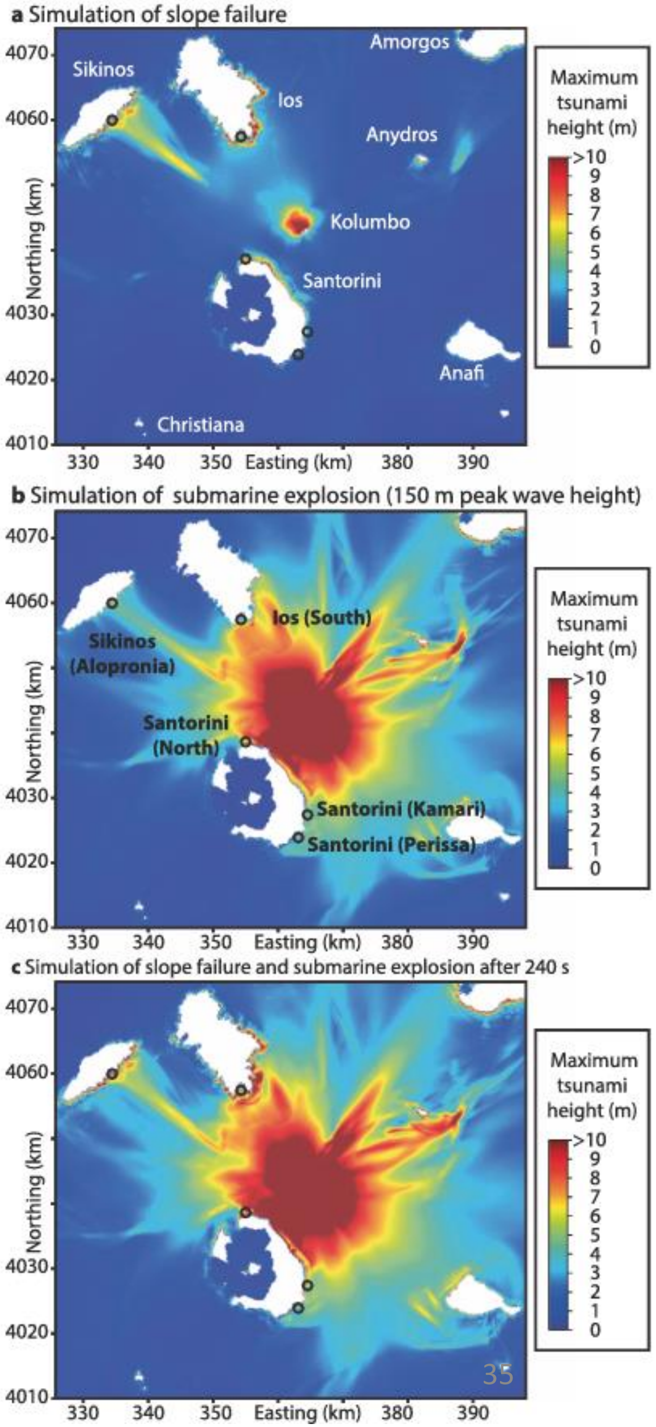




1650 Kolumbo Volcano Eruption & Tsunami Simulations

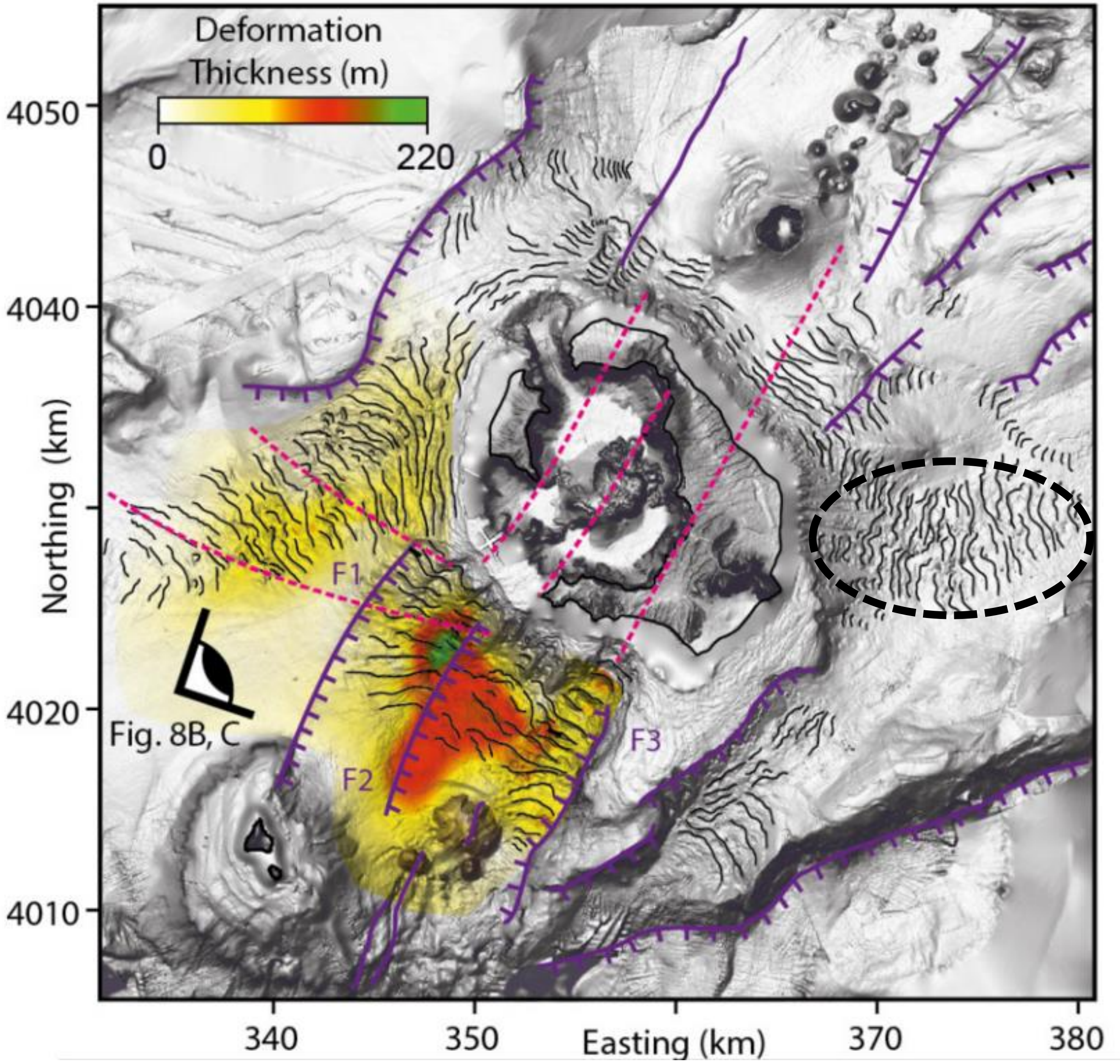




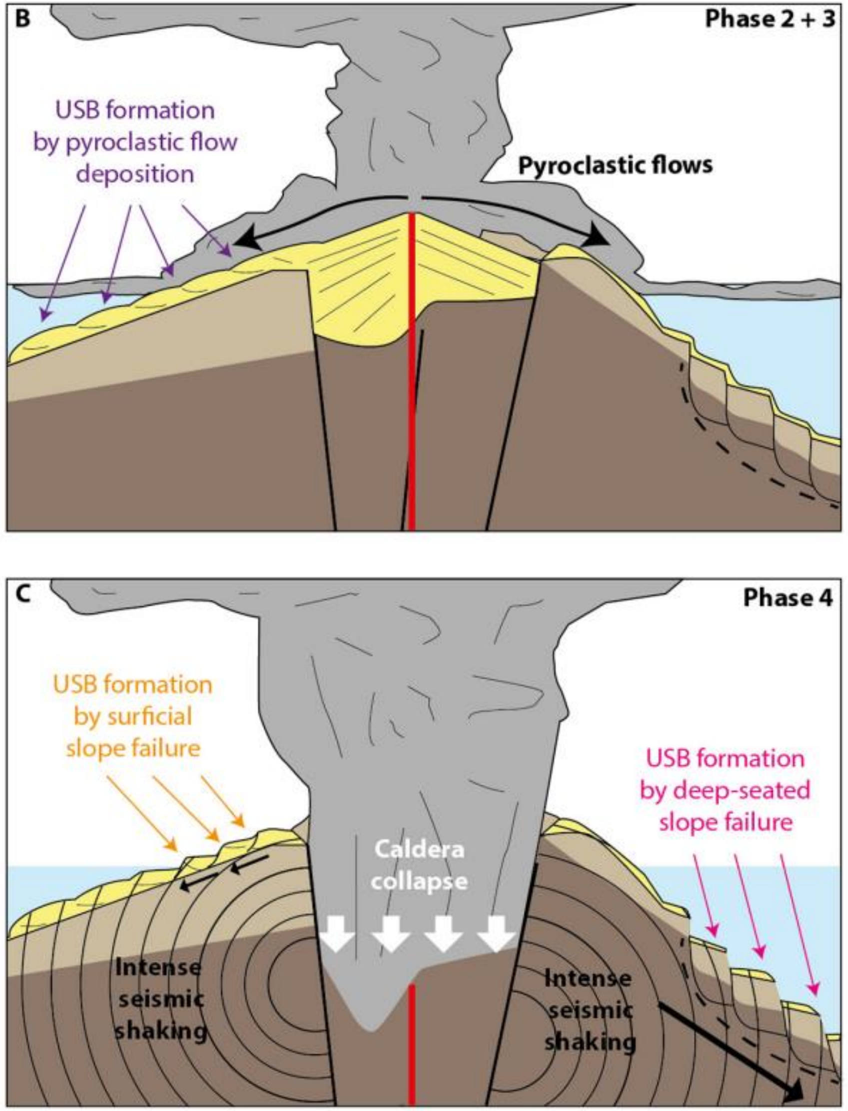


Karstens et al. (2023)

Minoan Eruption of Santorini, Submarine Landslides & Tsunami

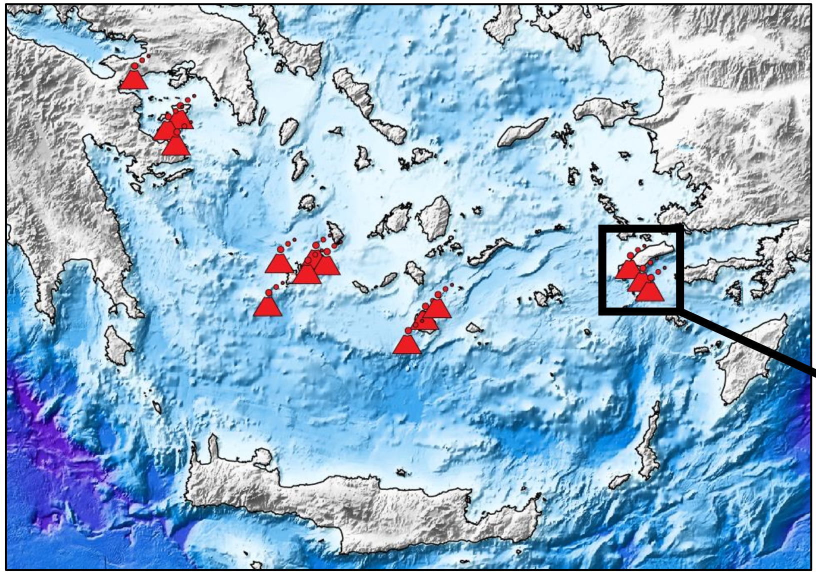


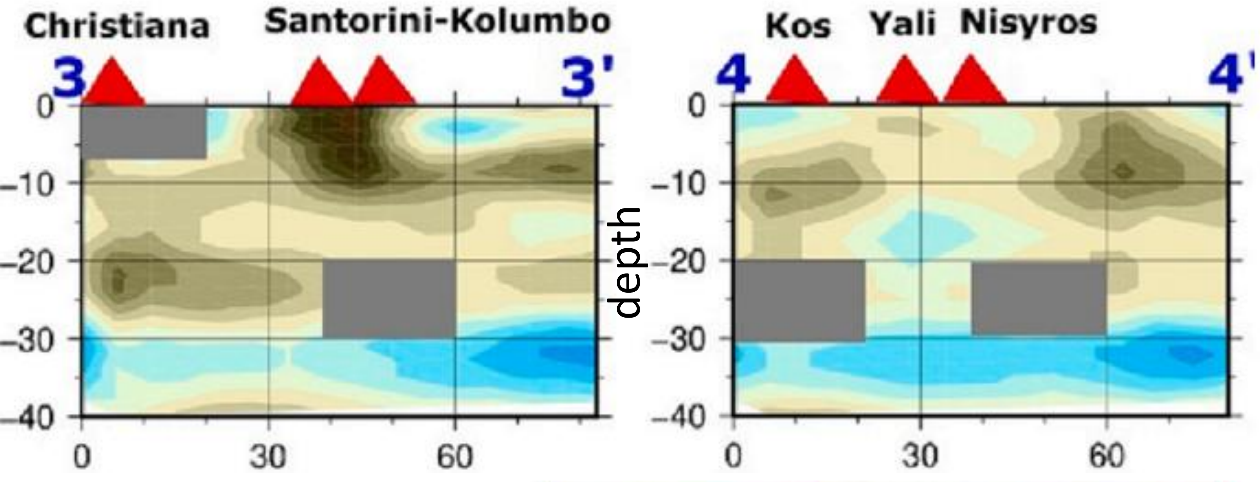
Karstens et al. (2023)

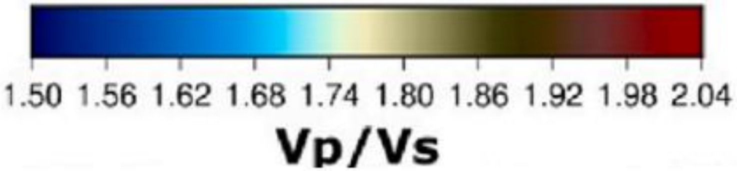


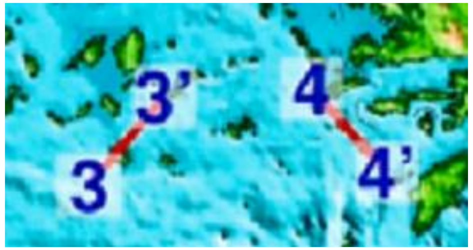
Active Volcanoes near Türkiye Coasts

Activity along Kos - Yali - Nisyros Volcanic System can effect Turkish coastal areas more severely (Ex: Datça, Bodrum, Bozburun)

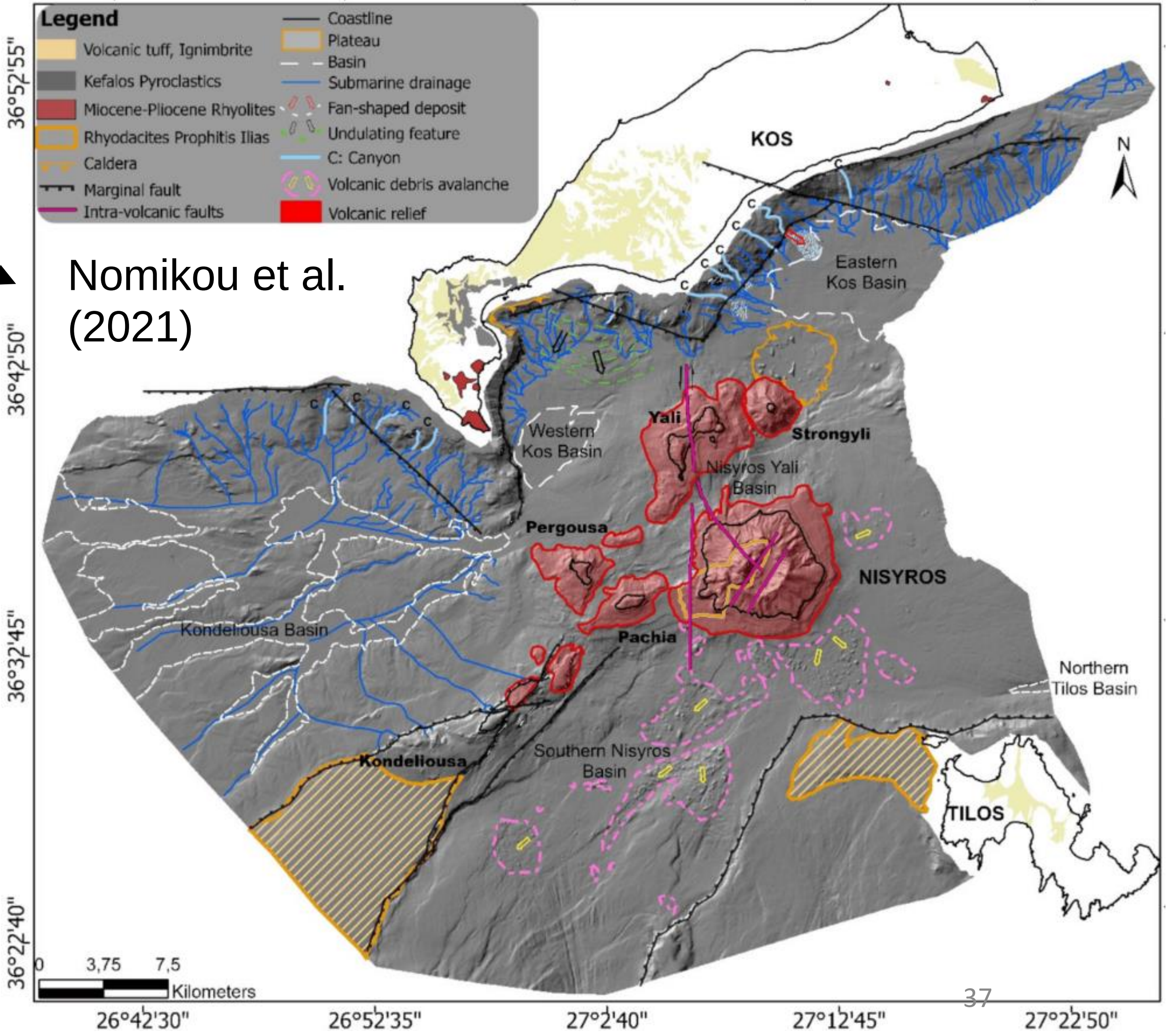








Ranjan & Konstantinou (2024)



Nomikou et al. (2021)

Summary of available Information on 1956 Amorgos Tsunami

- July 9, 1956, Offshore Earthquake 36.69° N, 25.92° E
- Amorgos-Astypalaea Island (South Aegean)

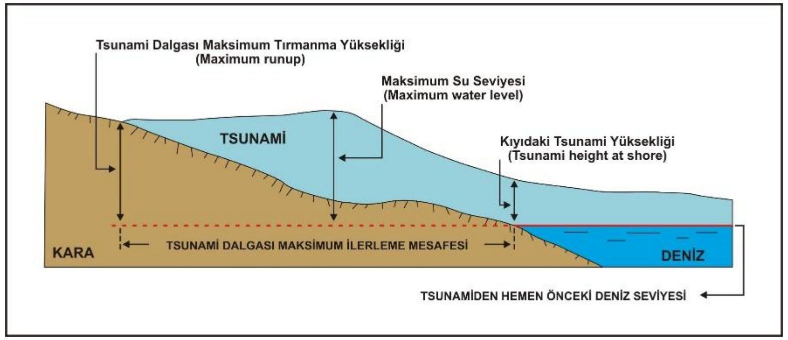
- Epicenter Intensity (I0): IX; Magnitude (Ms): 6.8; Tsunami Intensity (TI1): Amargos 6, Astypalaea 6
- Water Level Rise (Wr): Amorgos 30m, Astypalaea 20m, Pholegandros 10m, Patmos 4m, Kalimnos 3.6m, Crete 3m, Tinos 3m, Fethiye 1m
- Large waves have submerged fields on the islands. In Fethiye, the sea rose 1 m and a flood distance of 250 m was recorded; in Amargos, the submersion distance was observed to be 80–100m, in Astypalaea 400m, in Pholegandros 8m, and in Tinos 700m.
- It is believed to be associated with two shocks that occurred at 03:12 and 05:24.

INFORMATION OBTAINED FROM EYEWITNESSES – EFFECTS OF THE 1956 SOUTH AEGEAN TSUNAMI ALONG BODRUM COAST (2001 – 2004)

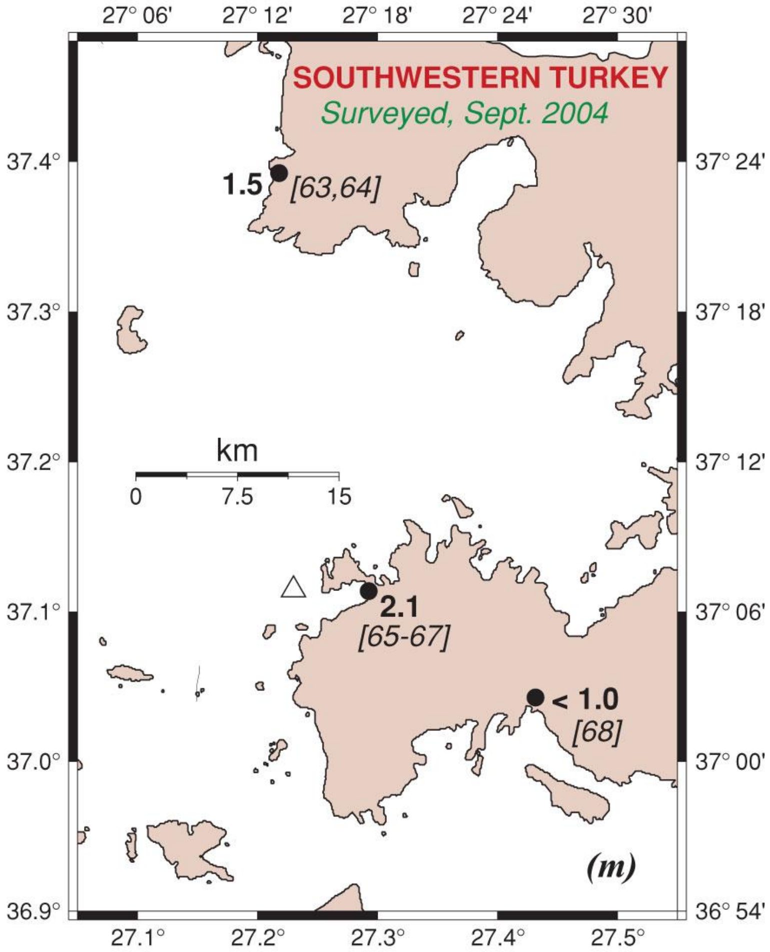
CIVIL. ENG. TARIK ERAY ÇAKIR

PROF. DR. AHMET CEVDET YALÇINER, ODTÜ

STUDY ON MEASUREMENT OF WAVE RISE HEIGHT ON THE COAST ACCORDING TO HIGHLY RELIABLE WITNESSES' NARRATIVES IN 2004



STUDY ON MEASUREMENT OF MAXIMUM WATER ELEVATIONS AT THE COAST ACCORDING TO HIGHLY RELIABLE WITNESSES' NARRATIVES DUE ON 2004



Okal, E., Synolakis, C., Uslu, B., Kalligeris, N., Voukouvalas, E., 2009.
The 1956 earthquake and tsunami in Amorgos. Greece. Geophys. J. Int. 178, 1533–1554.

2025 Earthquake Swarm & Potential Tsunami Scenarios

- January – February 2025: Ongoing seismic activity prompts alert status and raises concerns about potential tsunami impact in the region → further investigation needed.
- Available information regarding potential tsunami scenarios is examined and scenarios developed.
- Bathymetric/topographic database: Compilation of local available datasets & EMODnet (115 m resolution) and ASTER (30 m resolution) data sets.
- Tsunami modeling using NAMI DANCE

- **SHOD and HGM Türkiye**

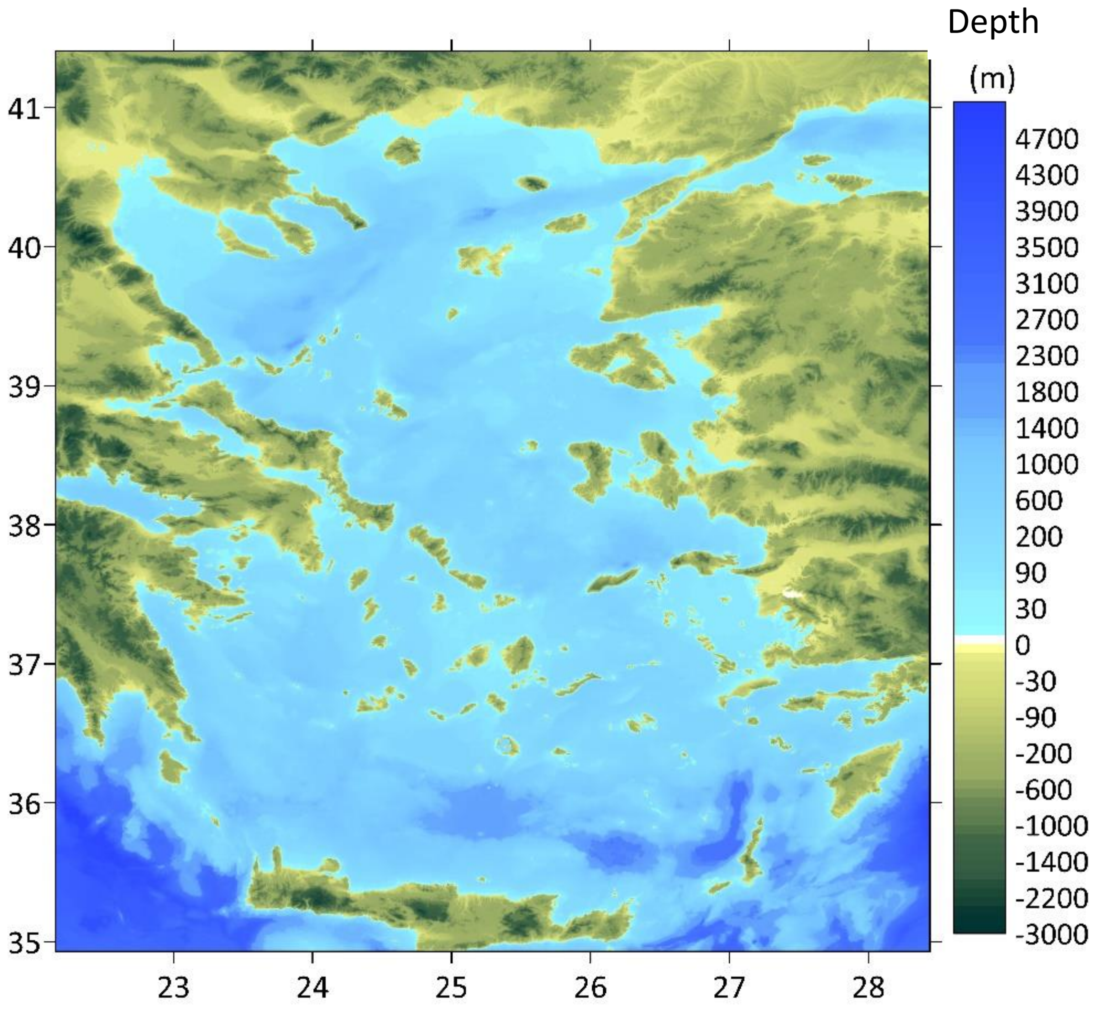


Figure 1: Map of the Aegean Sea bathymetry/topography used in the model

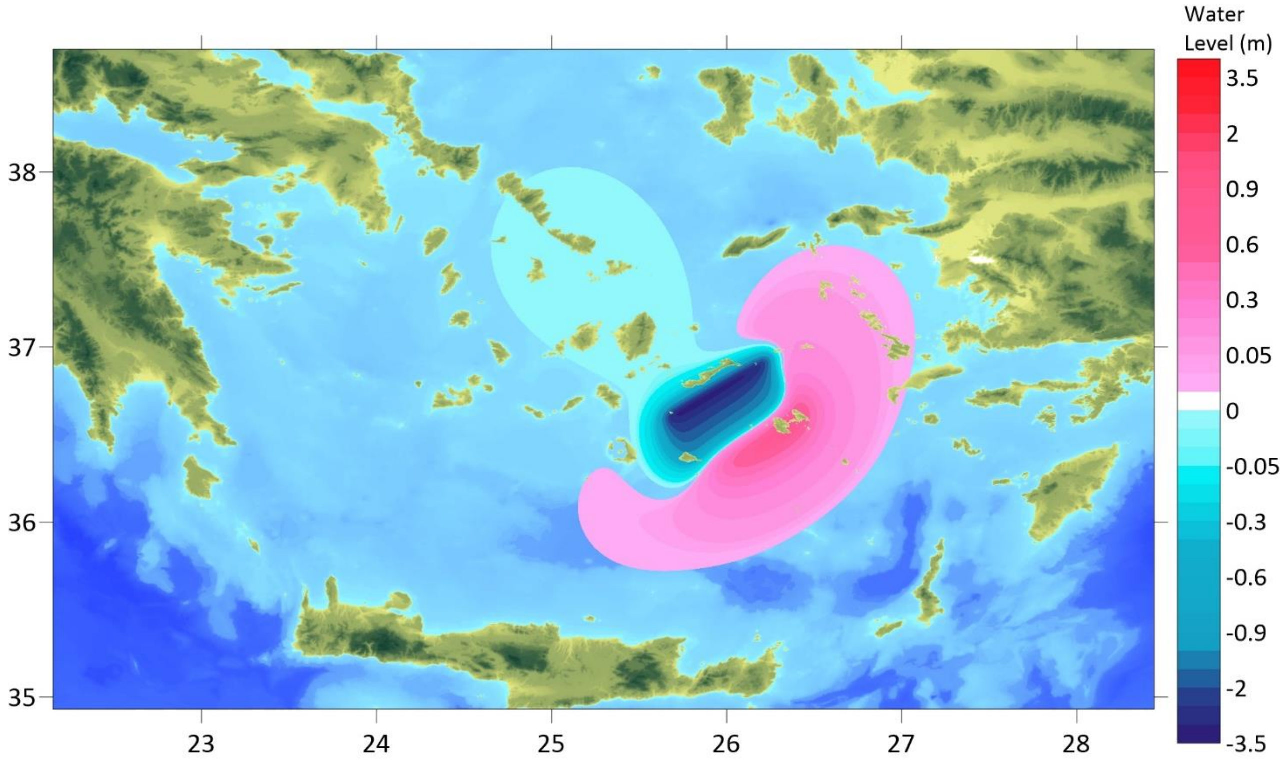
2025 Earthquake Swarm & Potential Tsunami Scenarios

Table 1: Summary of Selected Tsunami Scenarios

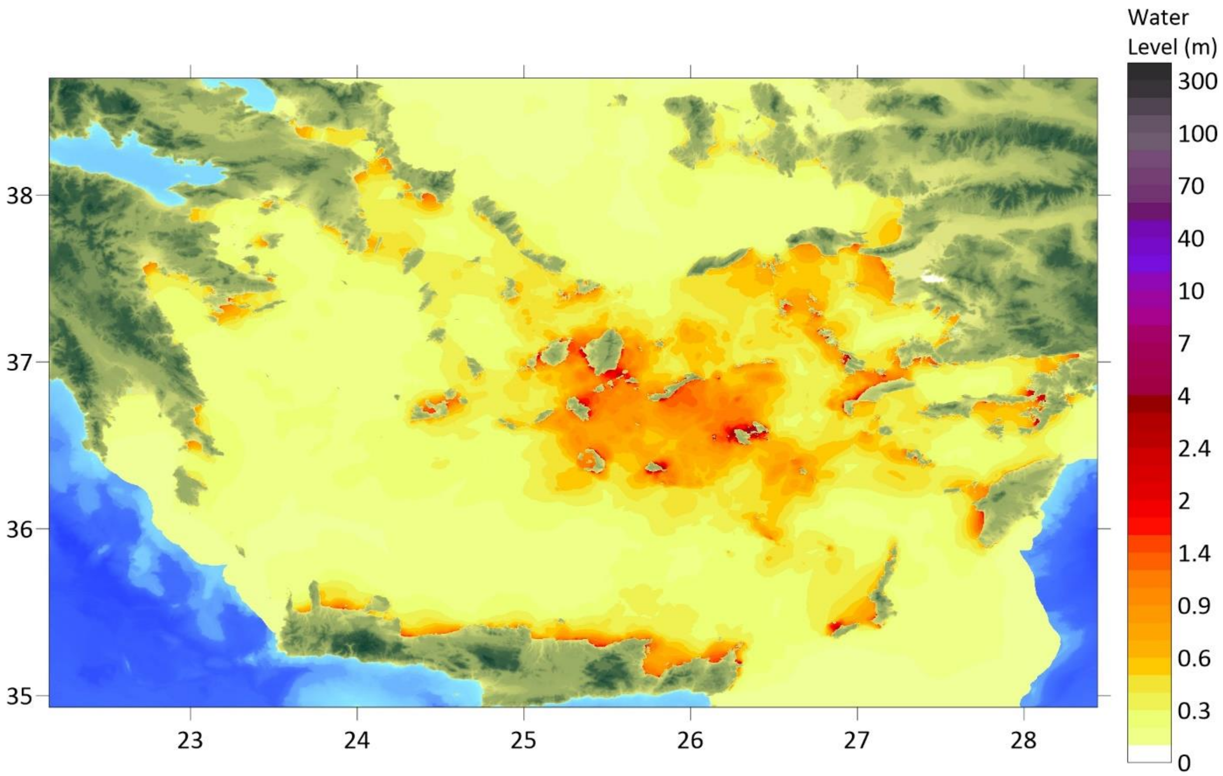
Scenario	Description
Scenario 1	1956 Amorgos earthquake and tsunami event (Past-event)
Scenario 2	Potential Anafi-Amorgos earthquake and tsunami (Dr. Arda Ozacar)
Scenario 3	Potential Landslide on Outer Slopes of Santorini Island
Scenario 4	Late Bronze Age Eruption and Caldera Collapse of Santorini Island (Past-event)
Scenario 5	Potential Kolumbo Submarine Volcano Explosion (Ulvrova et al. 2016) Explosive Energy: 3*10^14 – 5.4*10^16 Joules Water depth: 20-150 meters (average 80m). (Crater diameter: 3km) • Scenario 5a: Explosive Energy: 3*10^14 Joules • Scenario 5b: Explosive Energy: 5*10^15 Joules • Scenario 5c: Explosive Energy: 5.4*10^16 Joules

Scenario Simulations and Results

Scenario 1: 1956 Amorgos earthquake and tsunami event (Past-event)



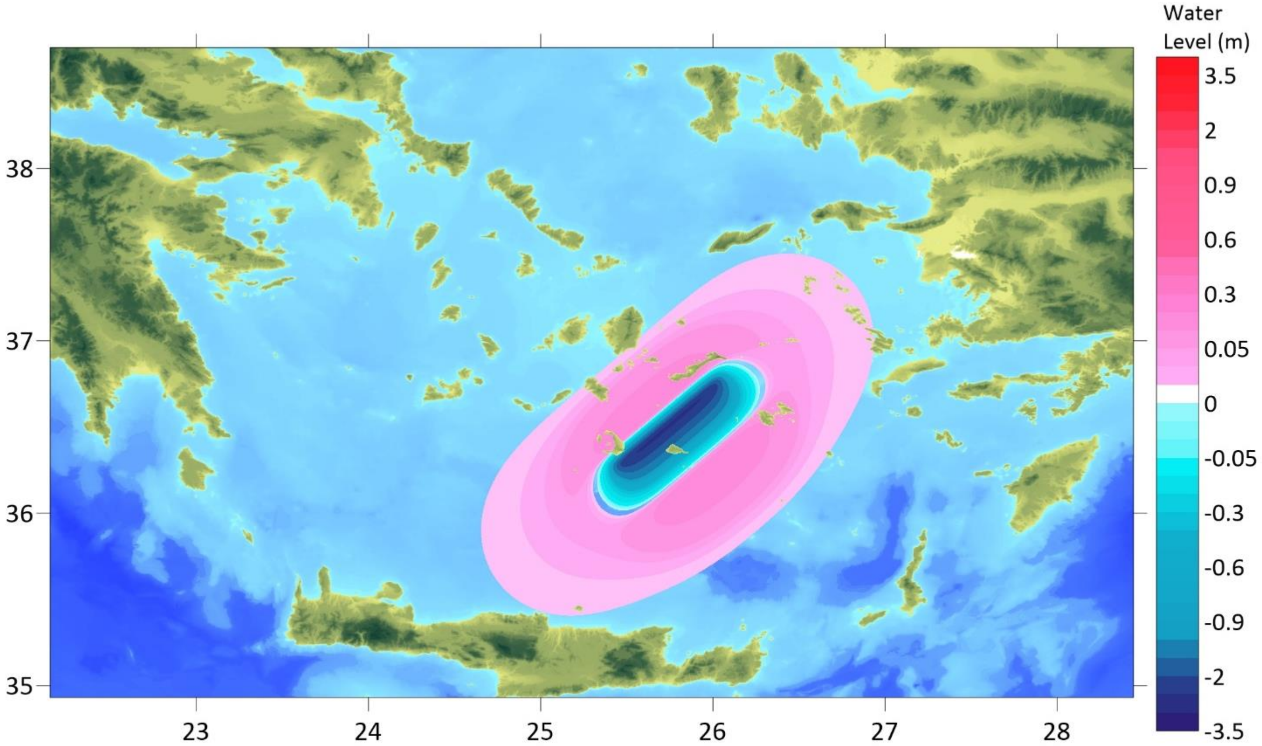
Initial sea surface displacement



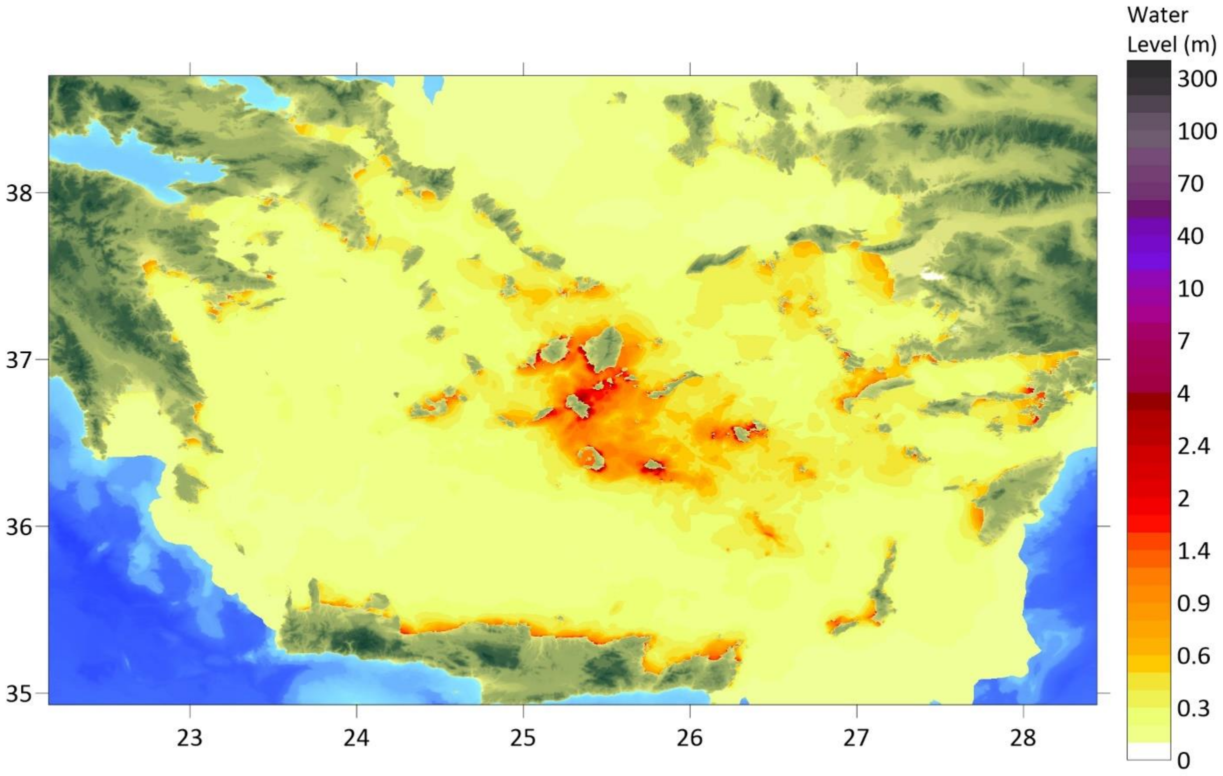
Distribution of maximum sea level computed during 6-hour simulation

Scenario Simulations and Results

Scenario 2: Possible Anafi-Amorgos earthquake and tsunami event (Dr. Arda Özacar)



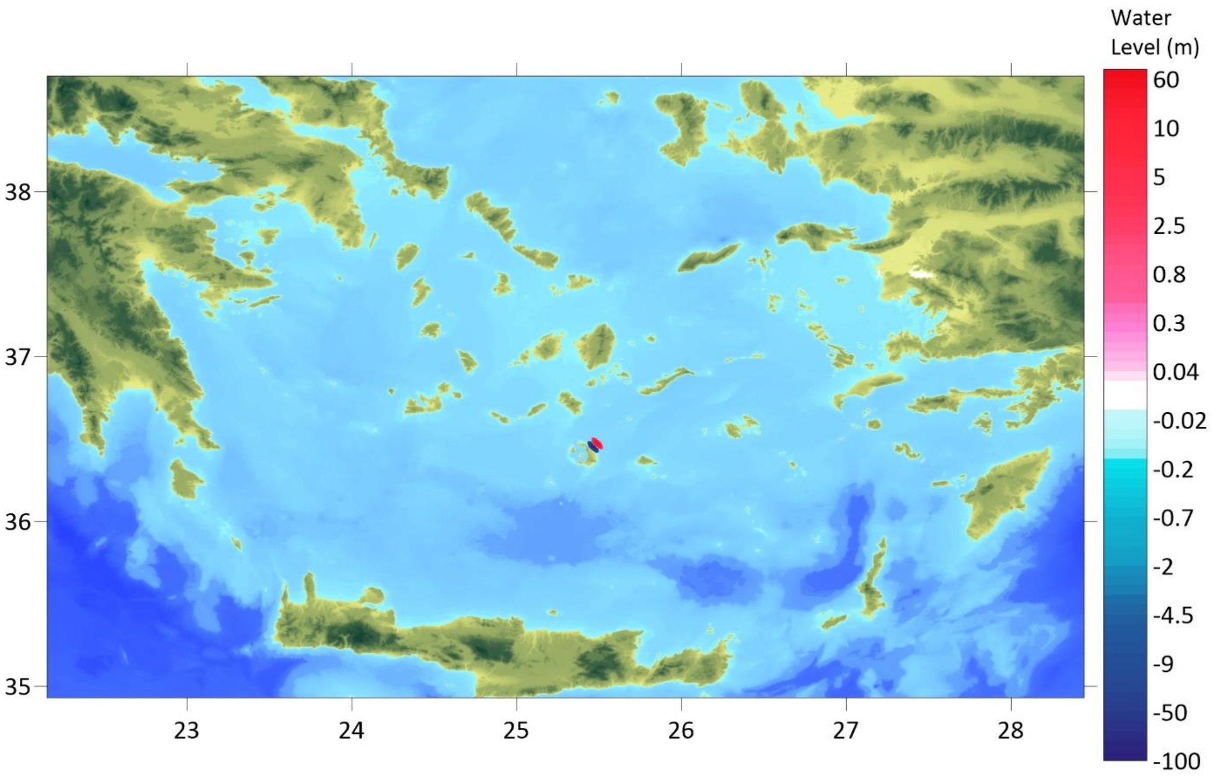
Initial sea surface displacement



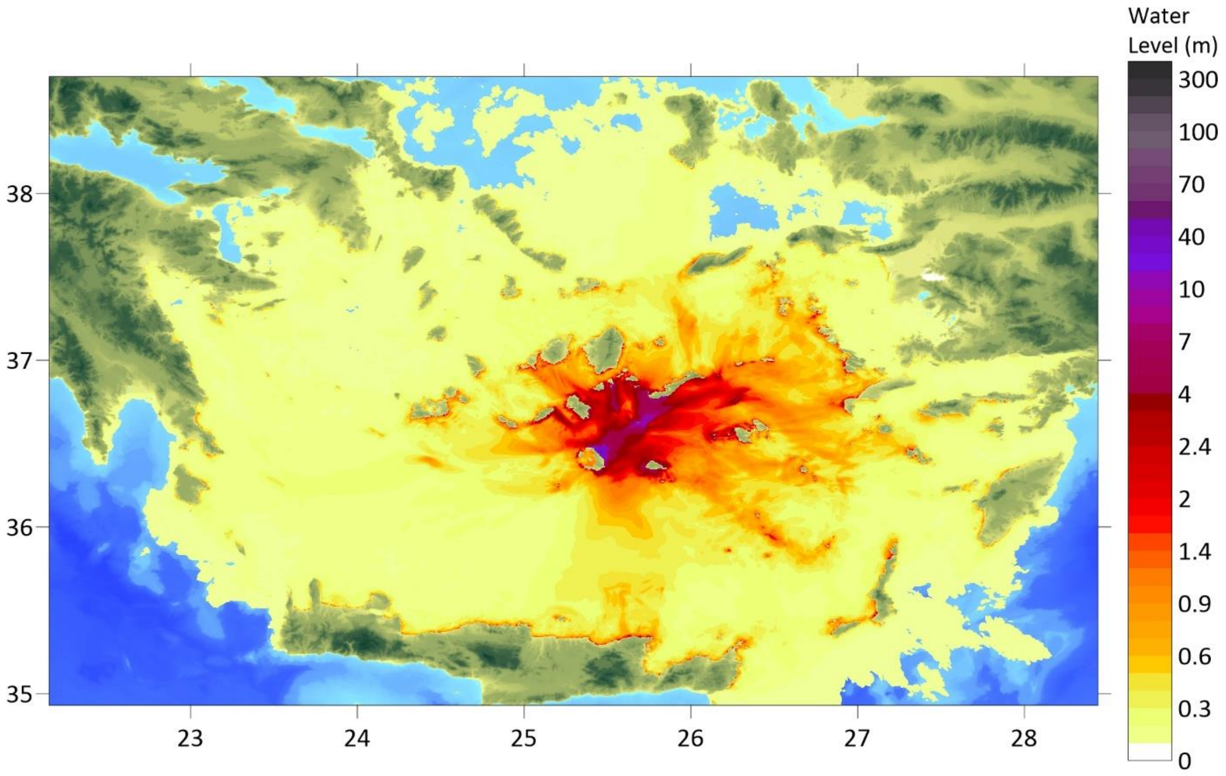
Distribution of maximum sea level computed during 6-hour simulation

Scenario Simulations and Results

Scenario 3: Possible Submarine Landslide on the Outer Slopes of Santorini Island



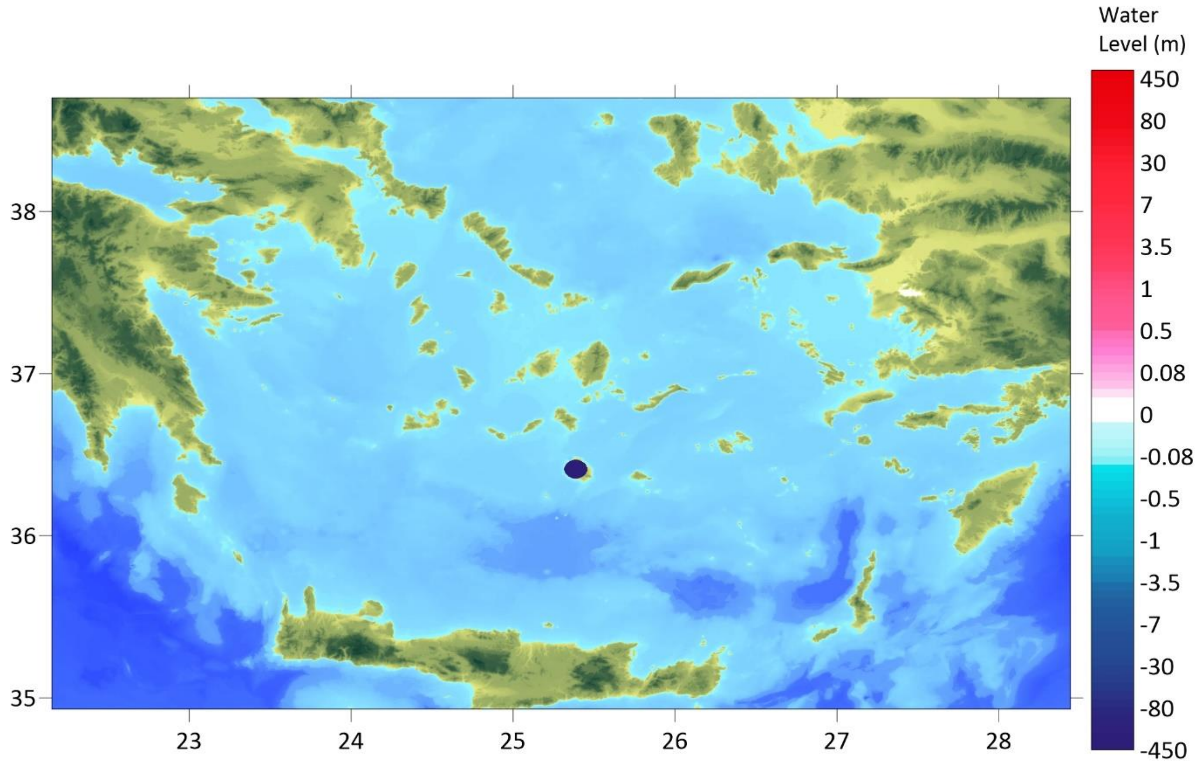
Initial sea surface displacement



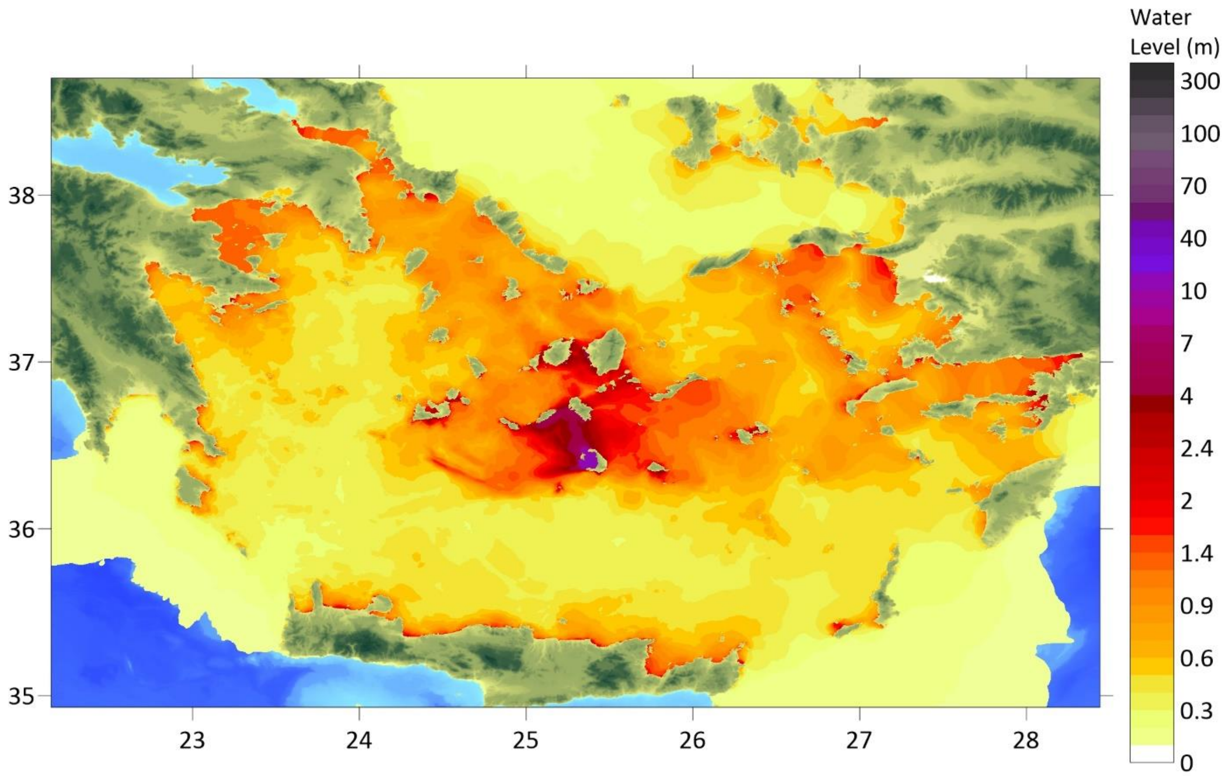
Distribution of maximum sea level computed during 6-hour simulation

Scenario Simulations and Results

Scenario 4: Santorini Island Late Bronze Age Eruption (Past-event)



Initial sea surface displacement

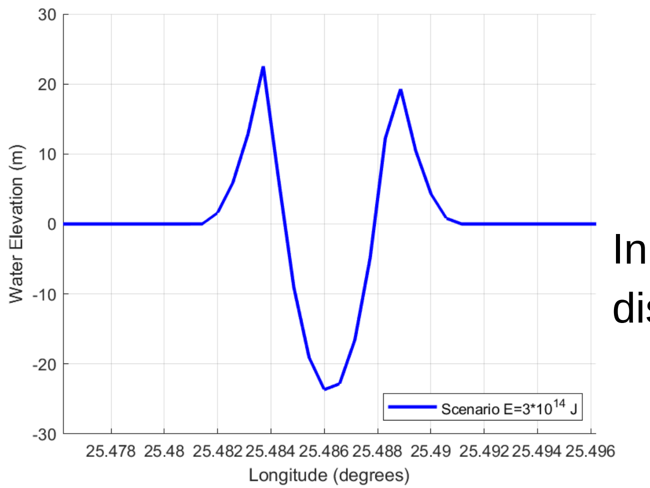


Distribution of maximum sea level computed during 6-hour simulation

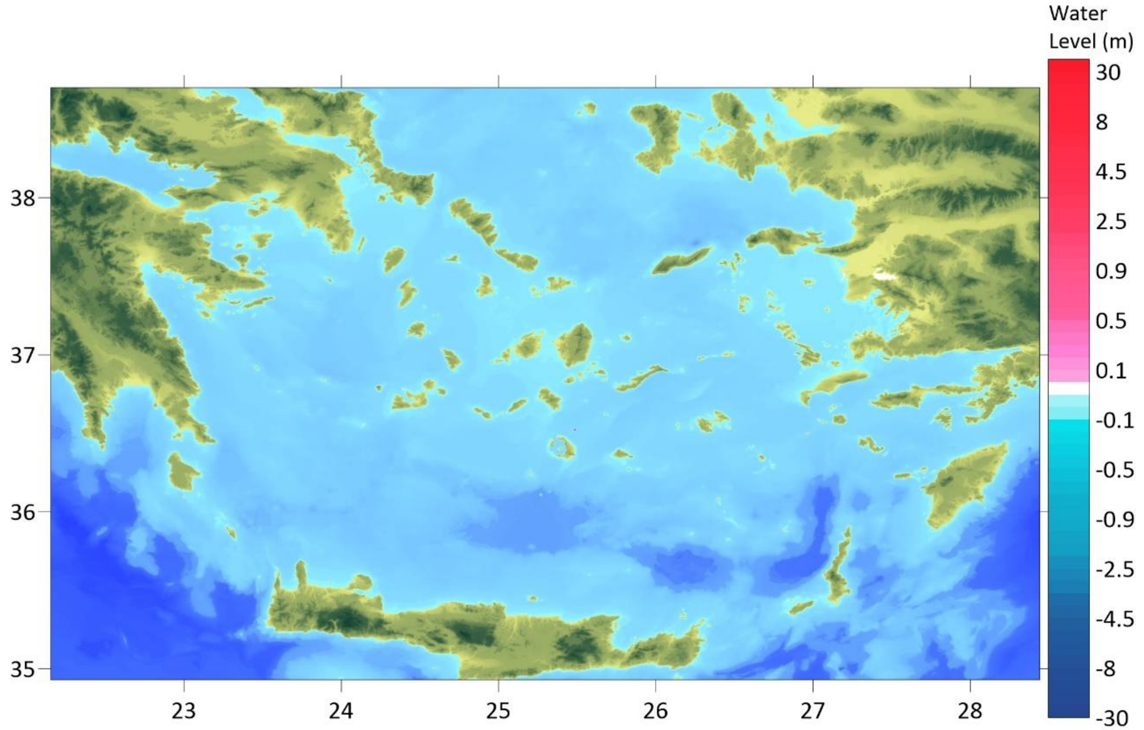
Scenario Simulations and Results

Scenario 5a: Possible Columbo Undersea Volcano Eruption

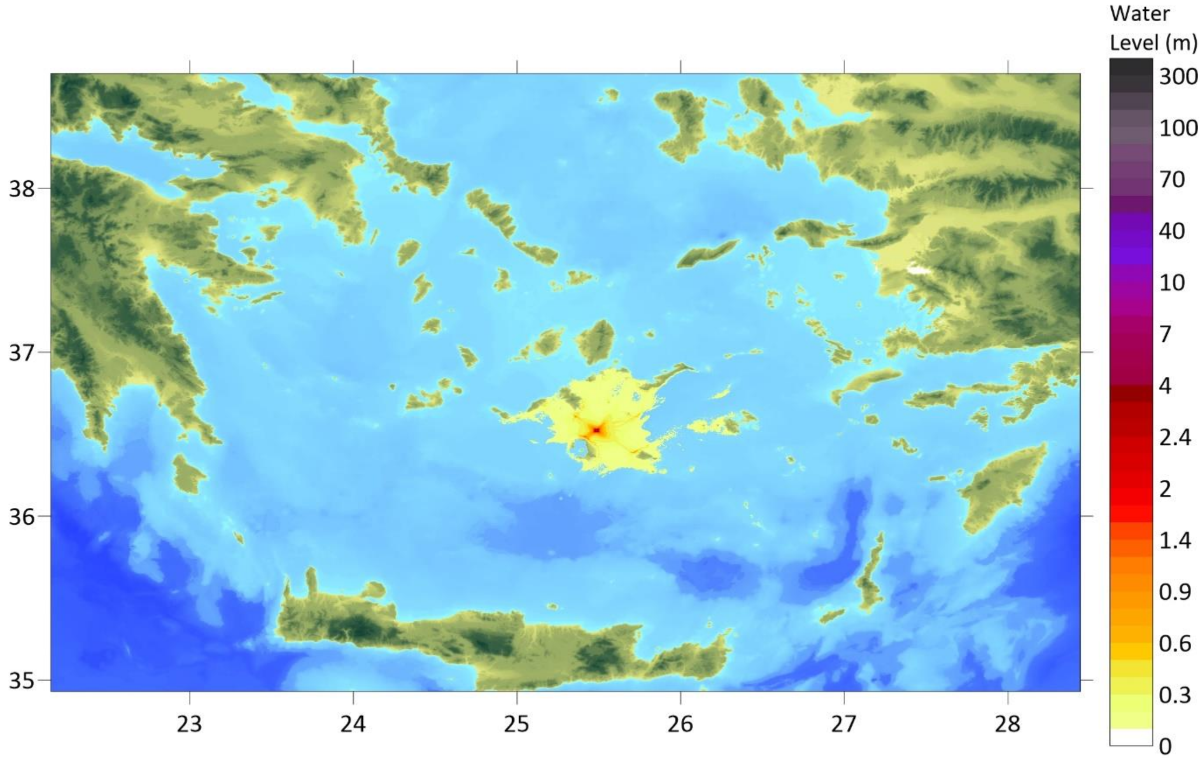
Explosion Energy: 3*10^14 Joules



Initial sea surface displacement profile



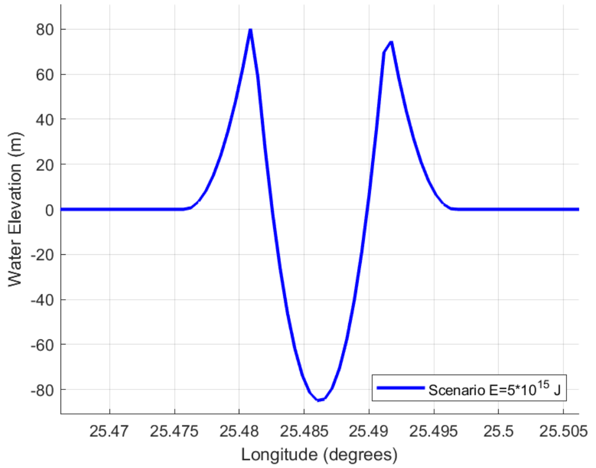
Initial sea surface displacement



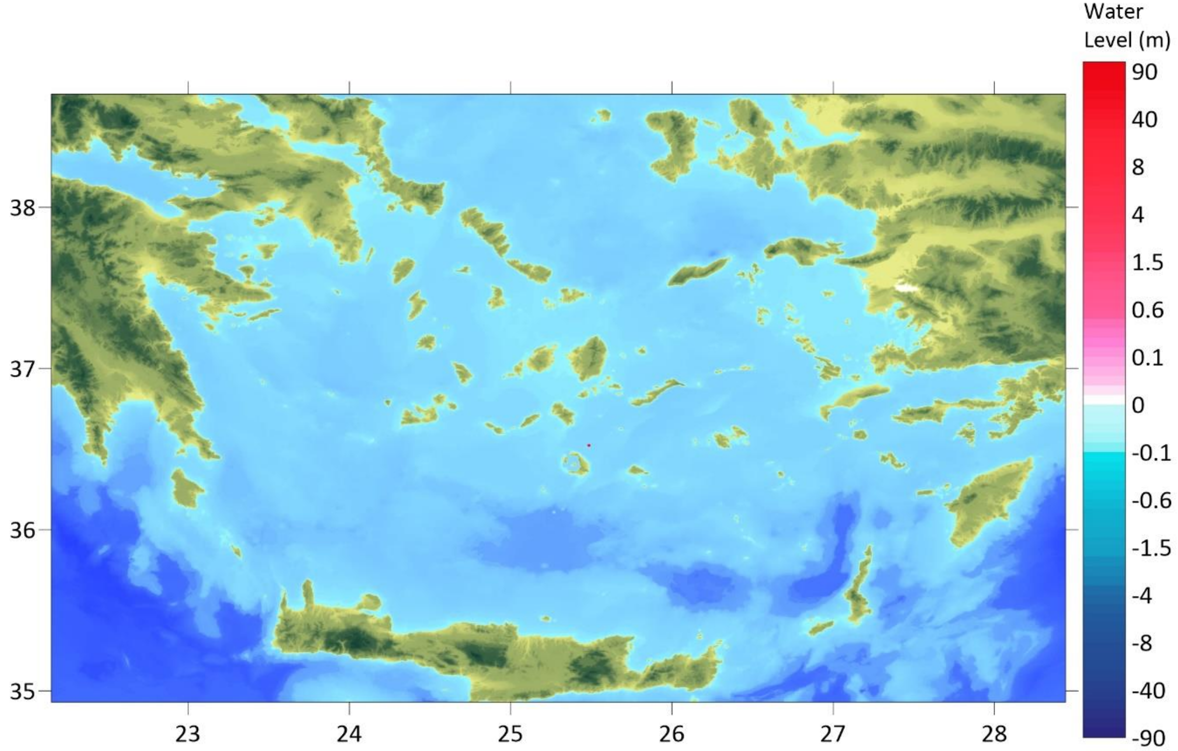
Distribution of maximum sea level computed during 6-hour simulation

Scenario Simulations and Results

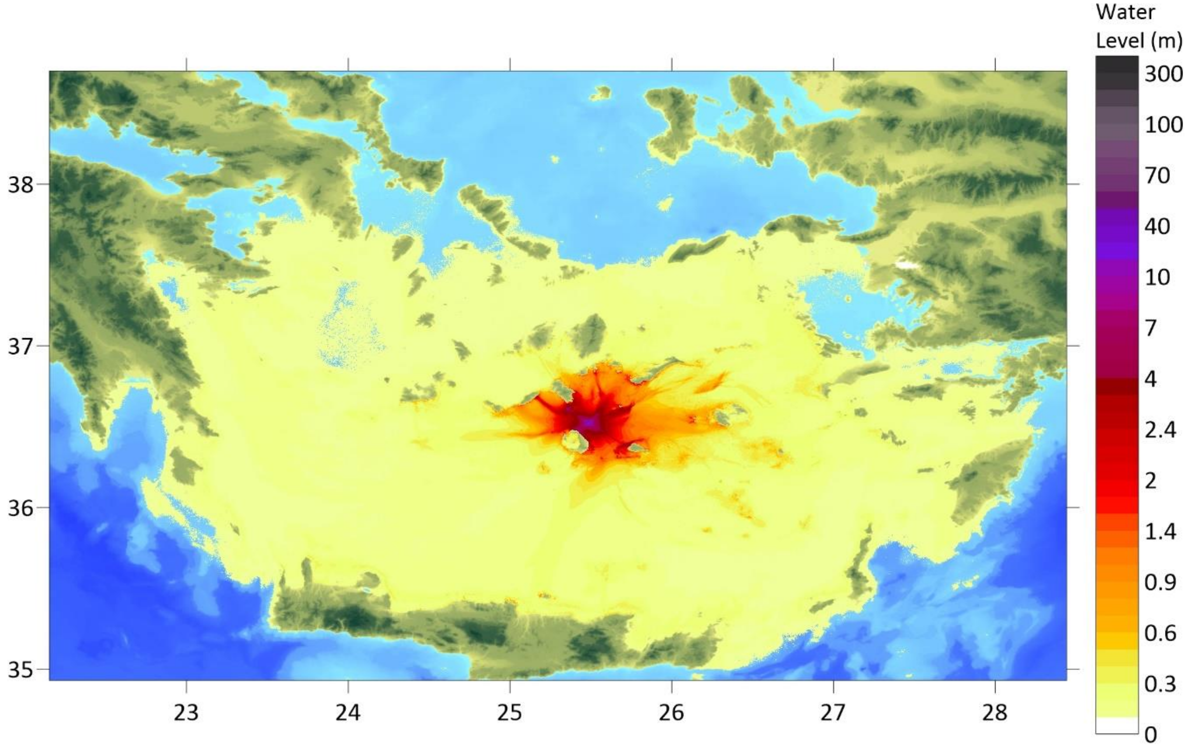
Scenario 5b: Possible Columbo Submarine Volcano Eruption Explosion Energy: 5*10^15 Joules



Initial sea surface displacement profile



Initial sea surface displacement

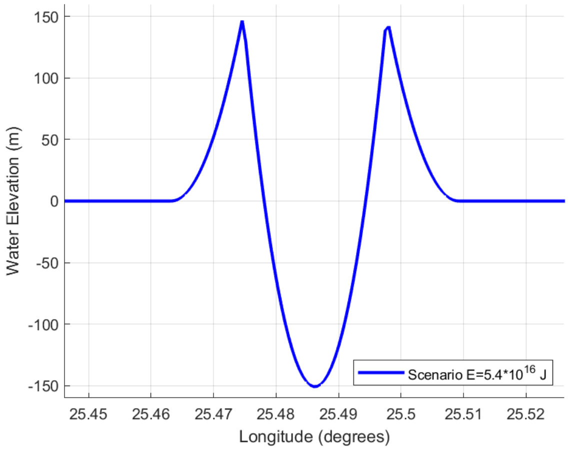


Distribution of maximum sea level computed during 6-hour simulation

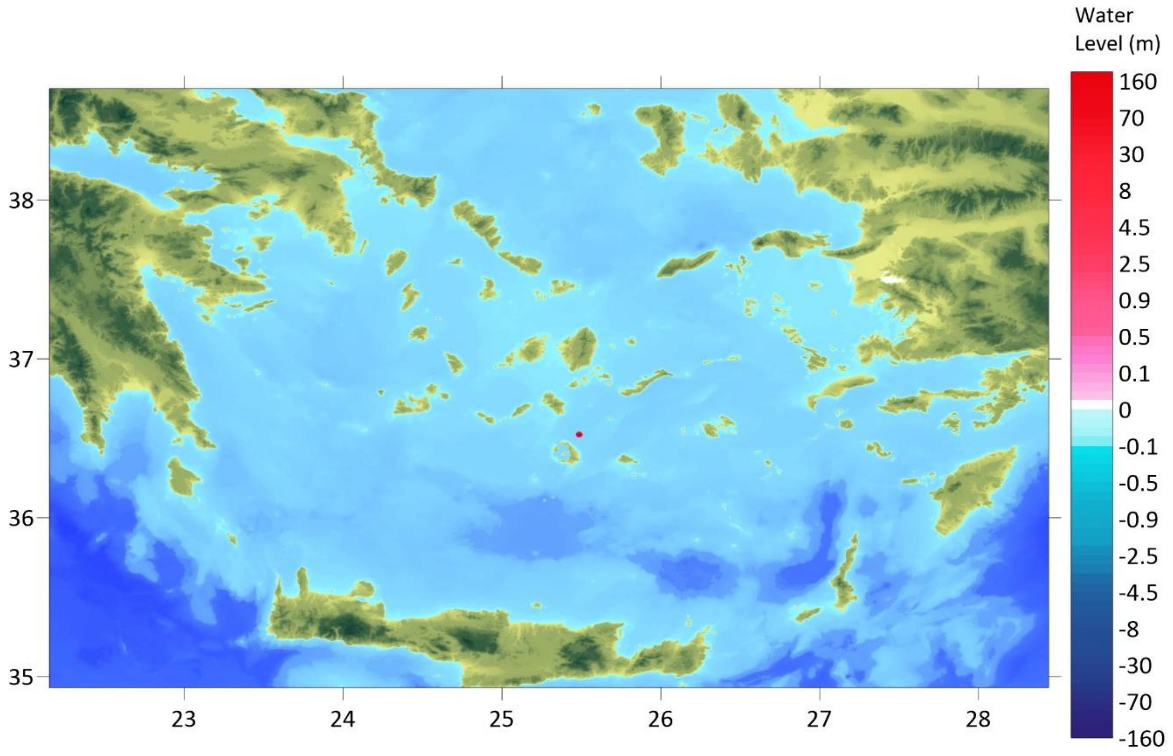
Scenario Simulations and Results

Scenario 5c: Possible Columbo Undersea Volcano

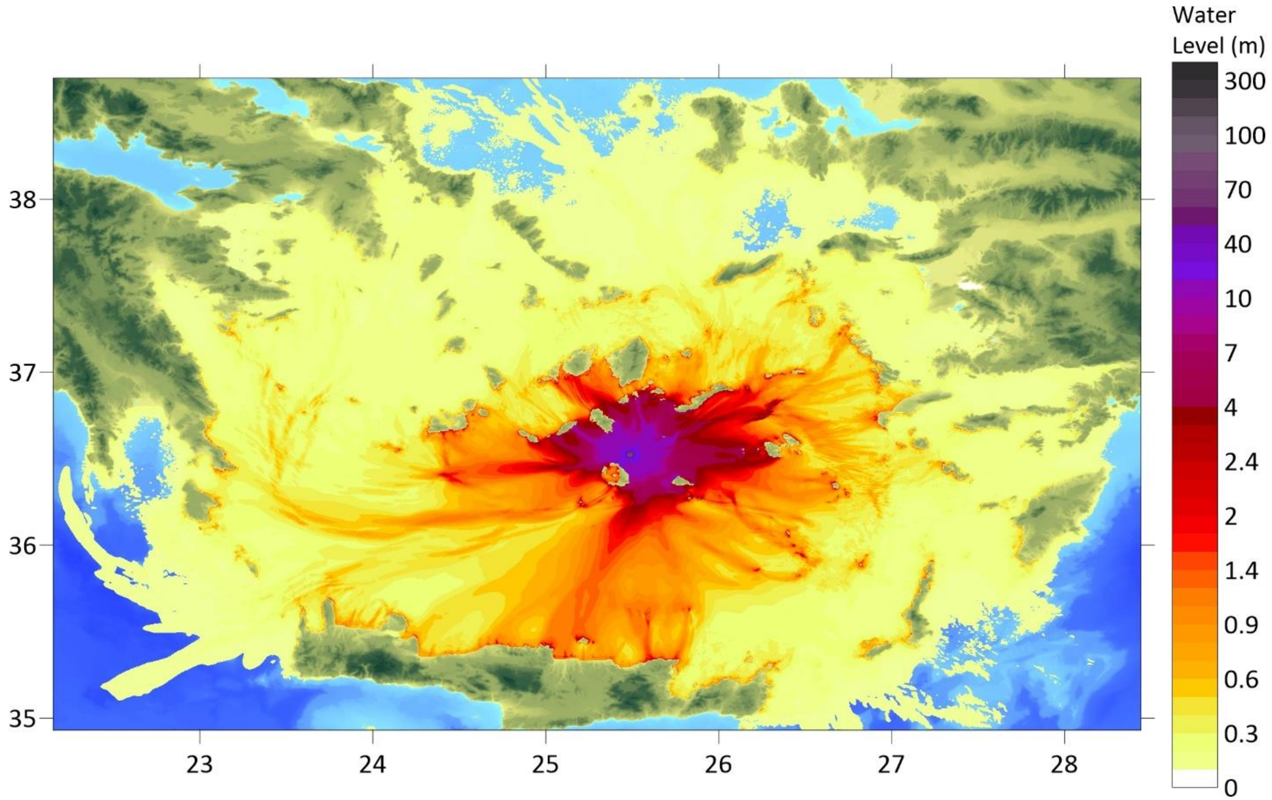
Eruption Explosion Energy: 5.4*10^16 Joules



Initial sea surface displacement profile



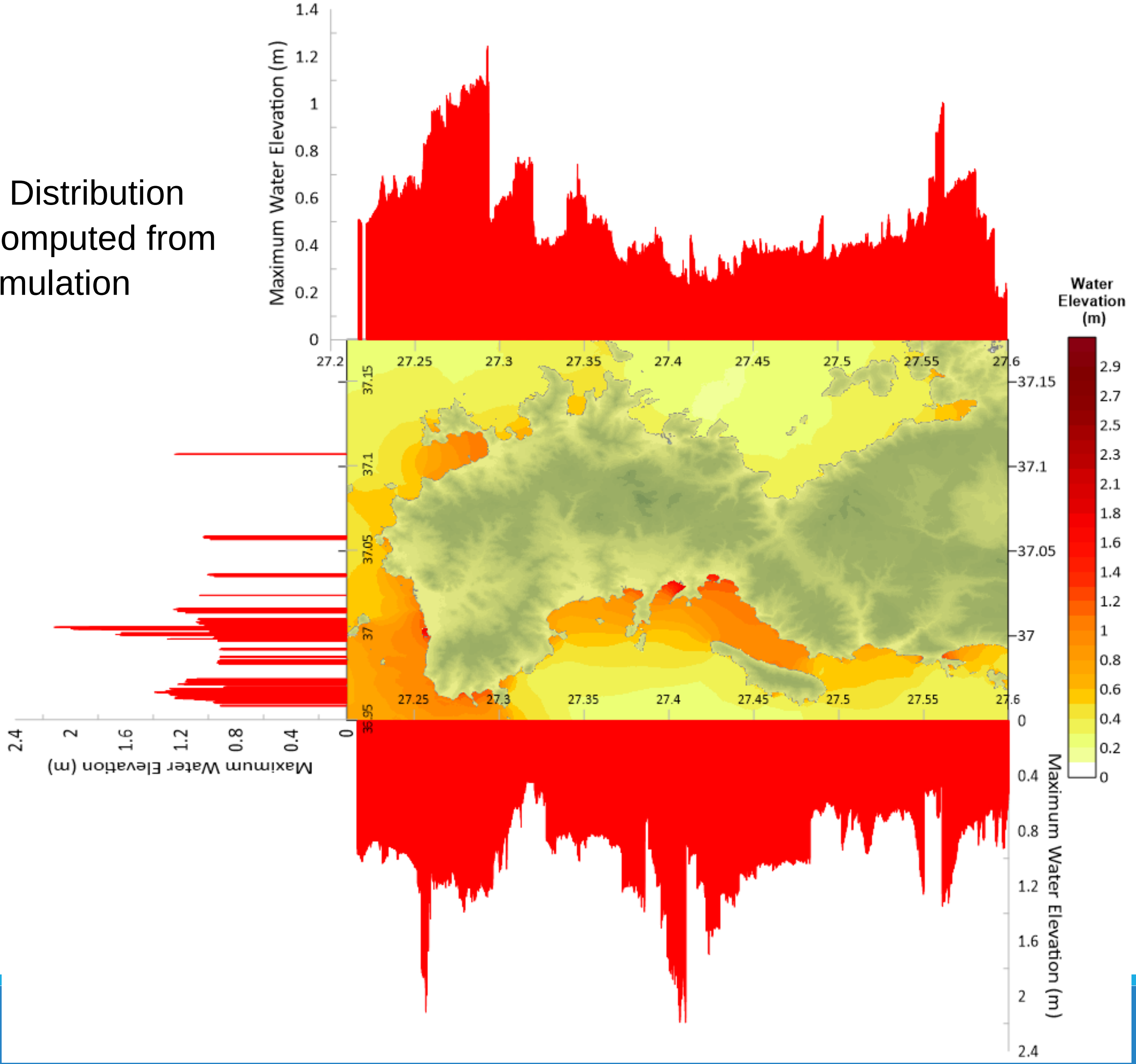
Initial sea surface displacement



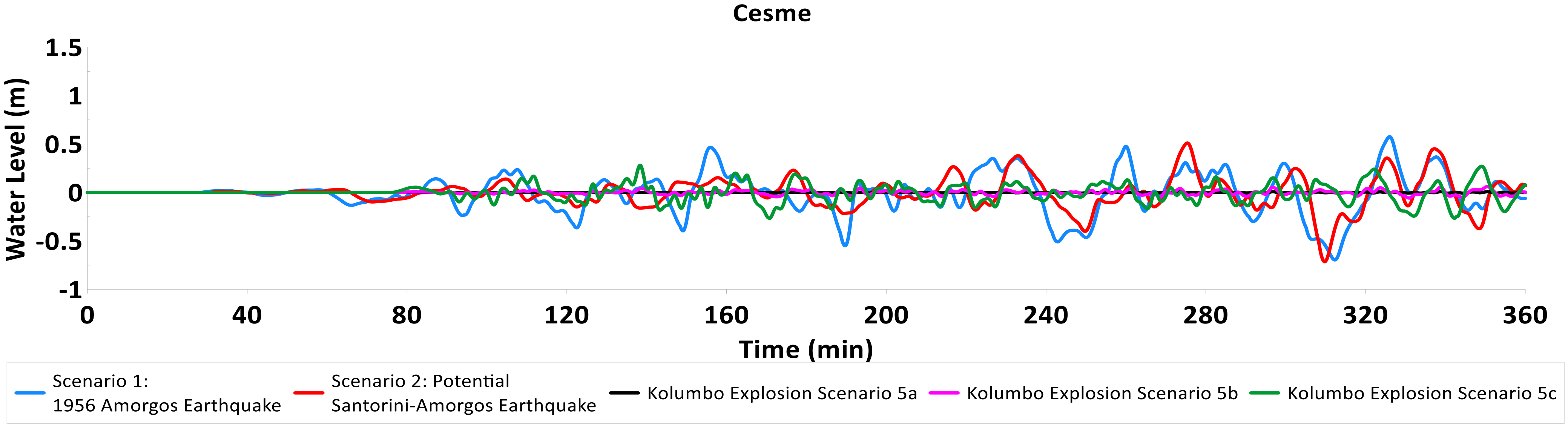
Distribution of maximum sea level computed during 6-hour simulation

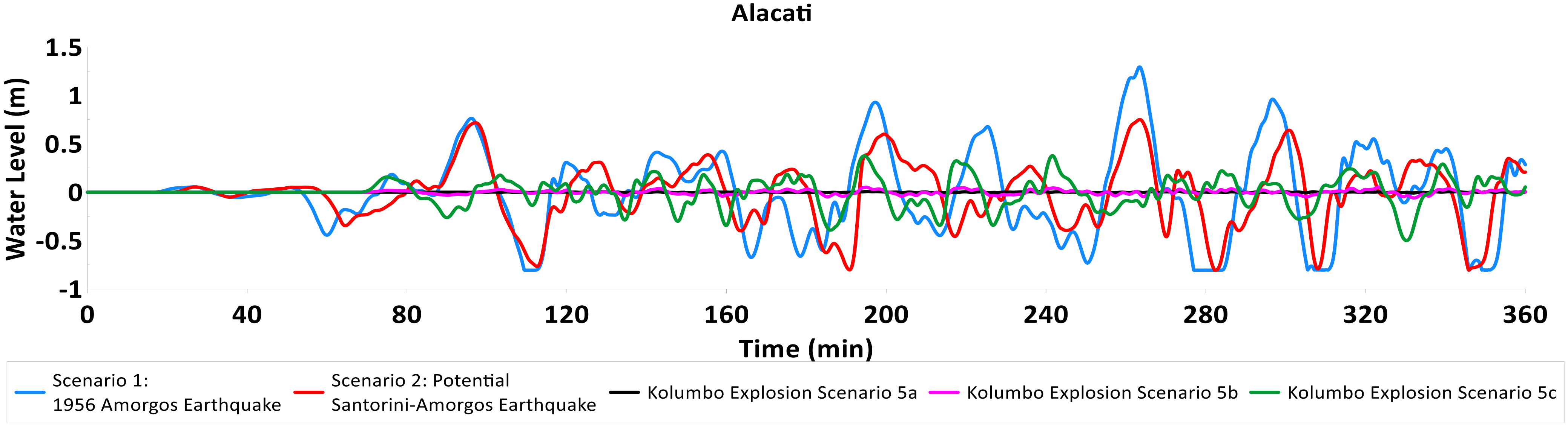
Scenario Simulations and Results

Maximum Water Elevation Distribution along Bodrum Peninsula computed from 1956 Amorgos Tsunami Simulation



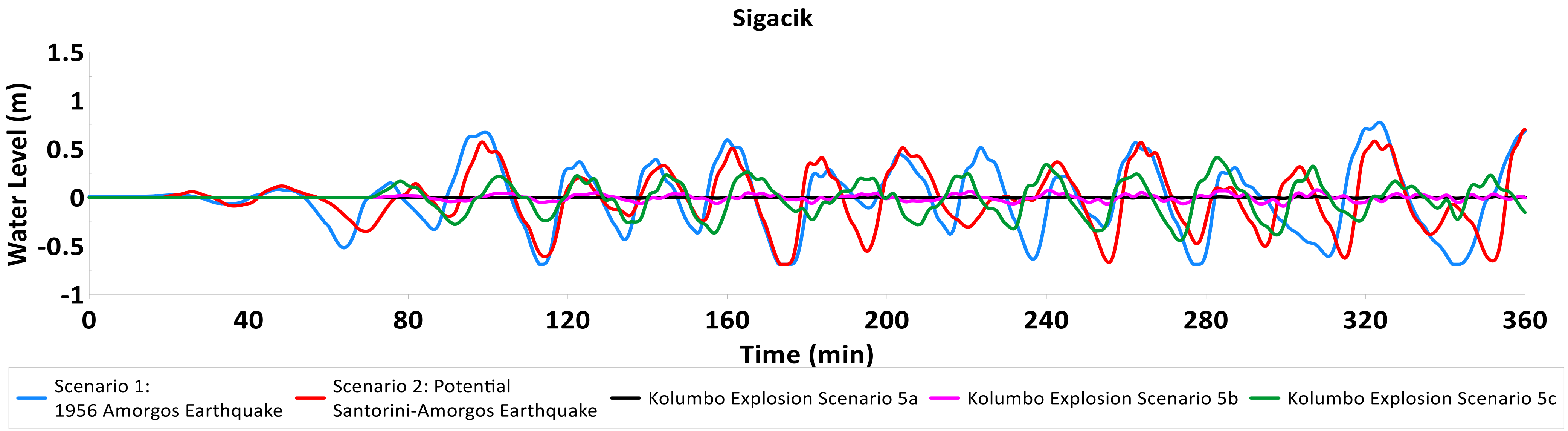
Scenario Simulations and Gauge Results

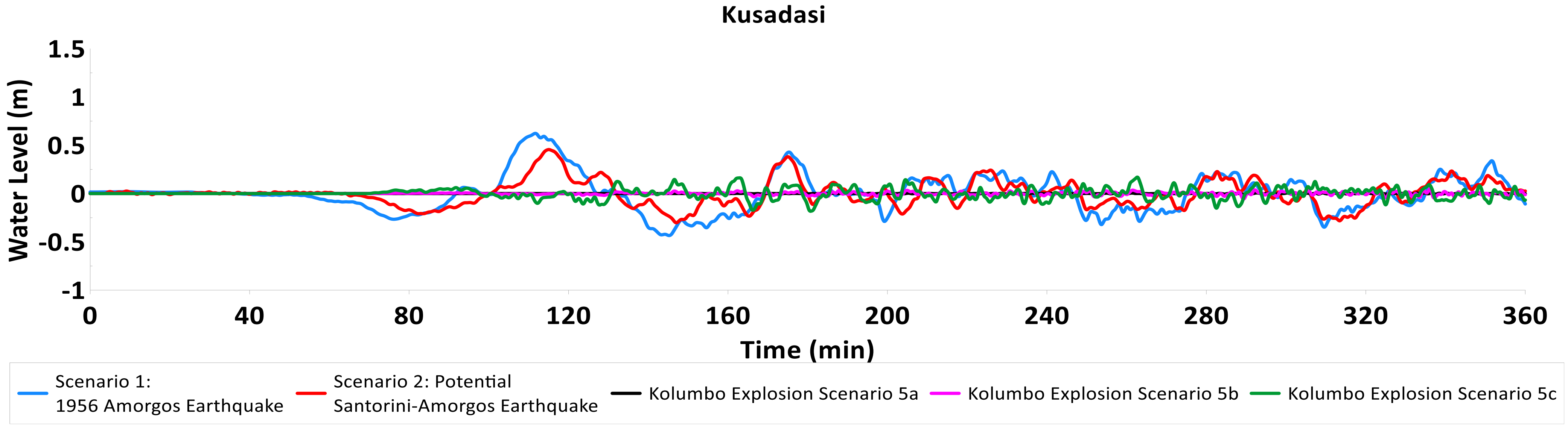




Time history of water levels computed for five different scenarios (1)

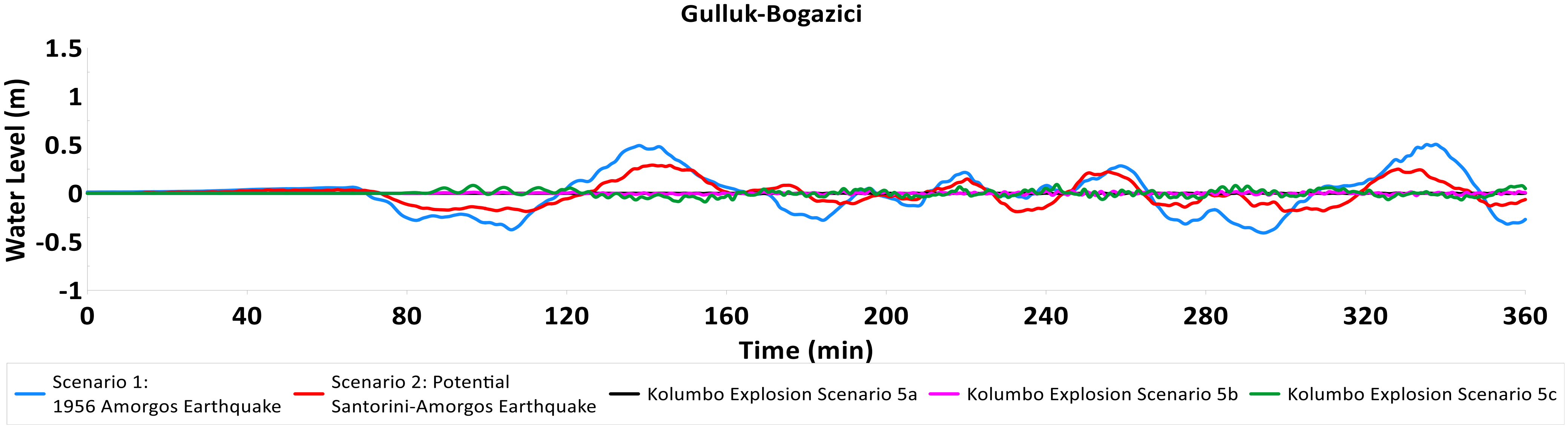
Scenario Simulations and Gauge Results

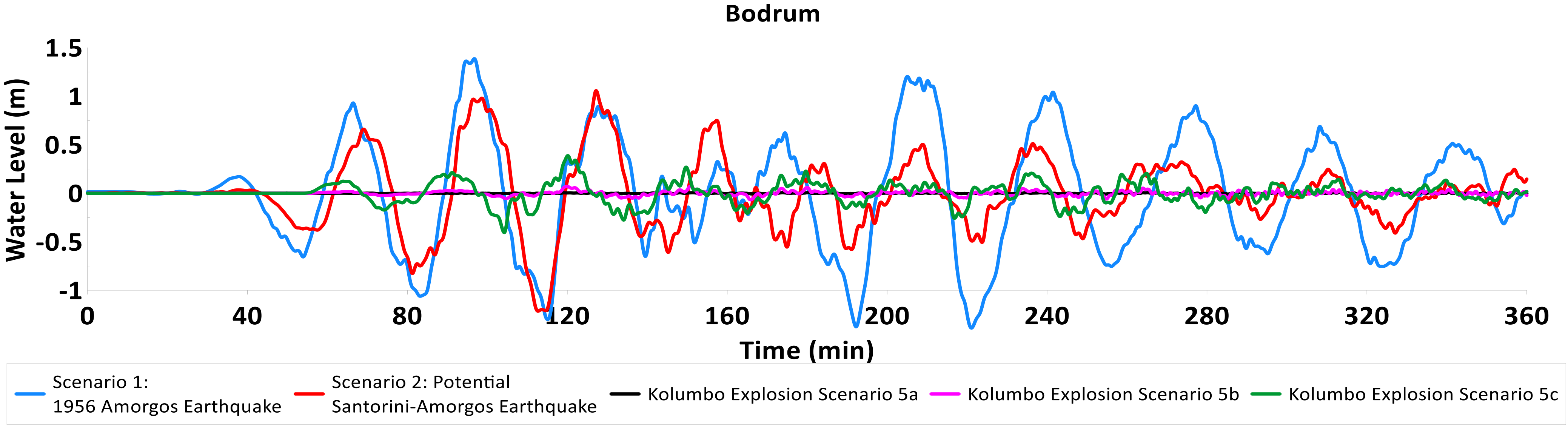




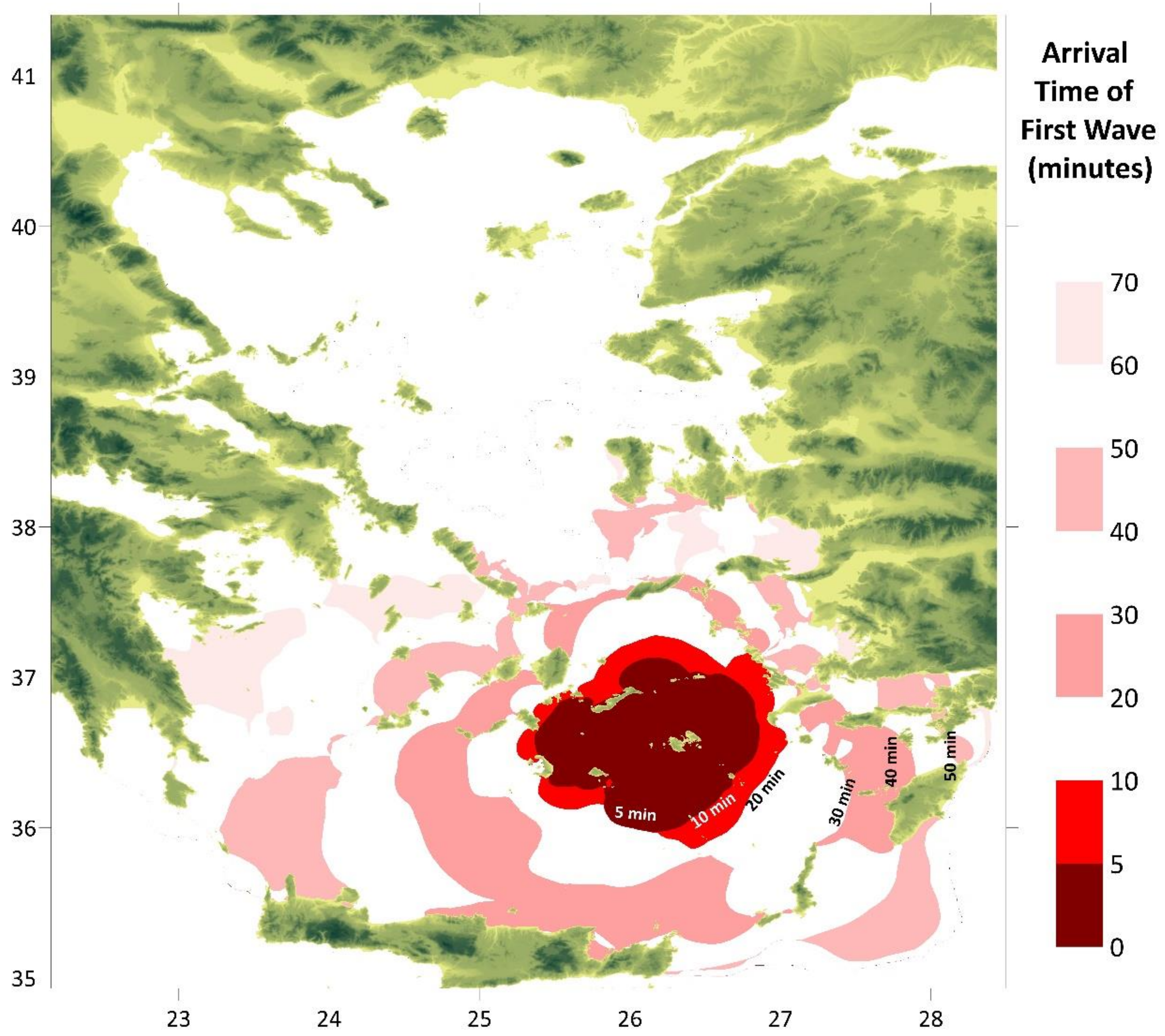
Time history of water levels computed for five different scenarios (2)

Scenario Simulations and Gauge Results

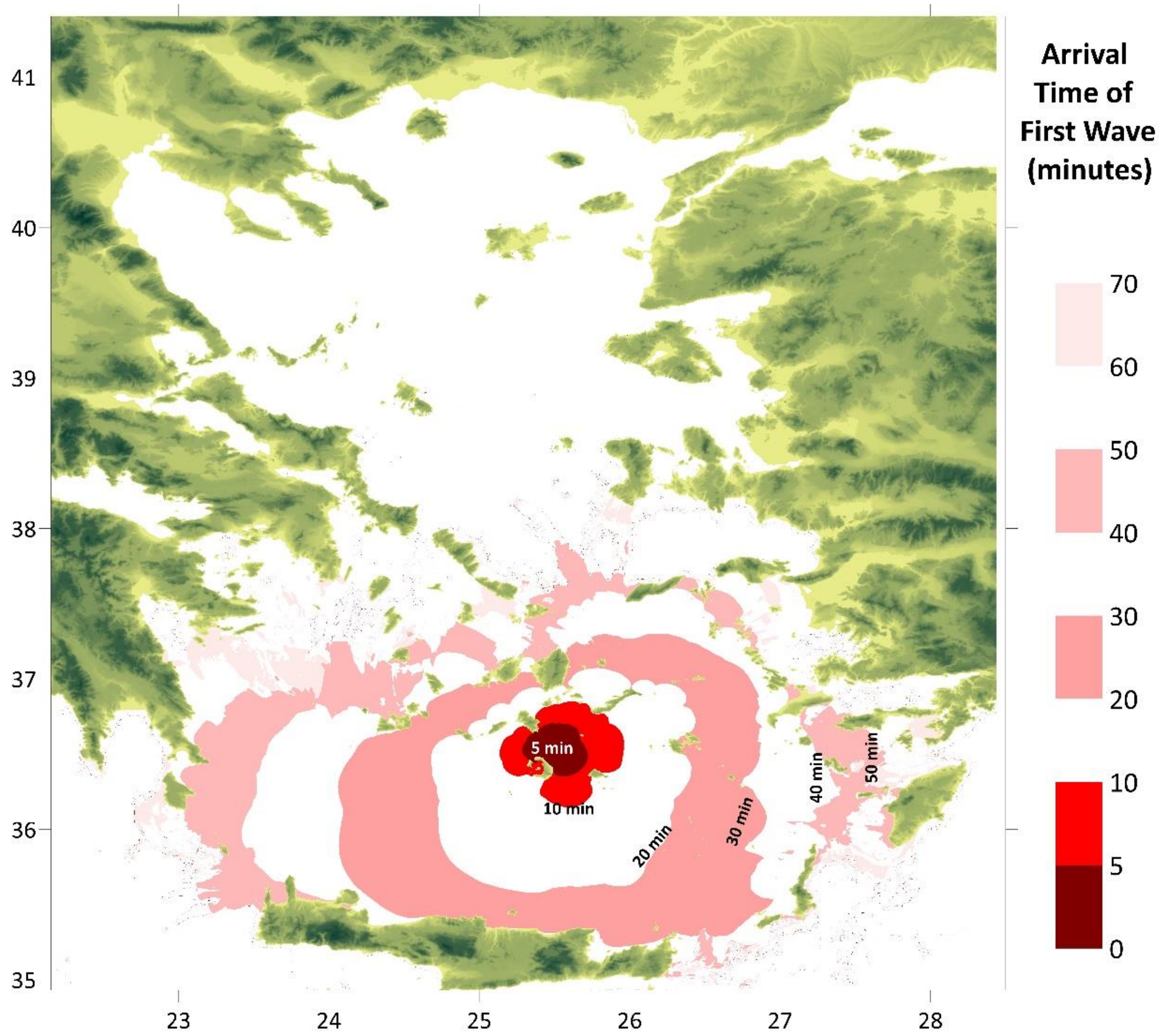




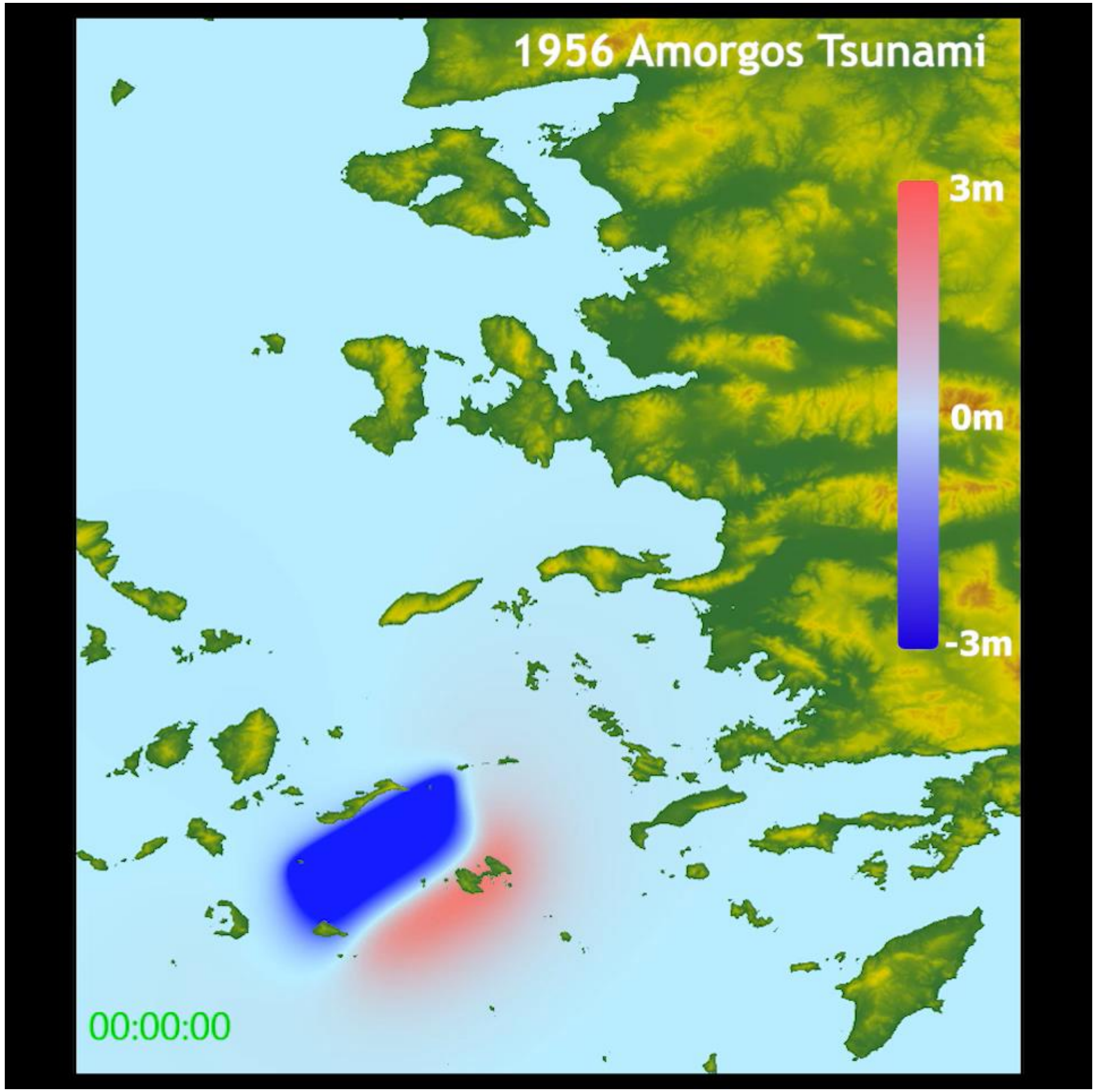
Time history of water levels computed for five different scenarios (4)



Tsunami arrival time contours according to 1956 Amorgos Tsunami Simulation (Scenario 1)

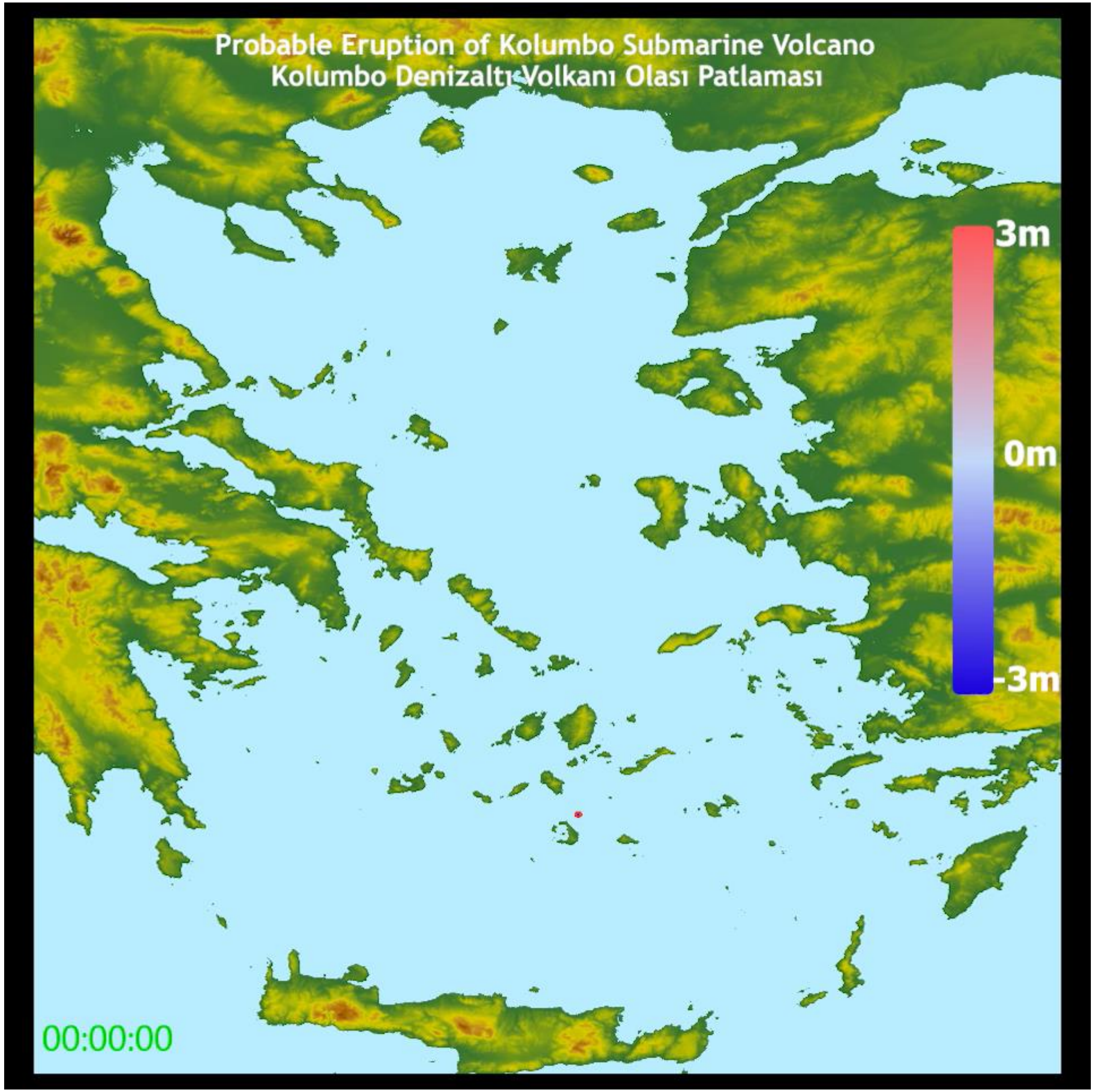


Tsunami arrival time contours according to potential Kolumbo explosion simulation (Scenario 5c)



Scenario 1: Tsunami propagation due to the 1956 Amorgos earthquake

https://drive.google.com/file/d/1wjMObvTzxQOunDwVEzx0GU3y06HdFVKn/view?usp=sharing



Scenario 5: Possible Kolumbo Submarine Volcano Eruption (Ulvrova et al. 2016) Explosion Energy: 10^14, 10^15, 10^16 Joules)

ACKNOWLEDGEMENT

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THANK YOU!

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