Location of Marmara Sea Earthquakes Using Marmara Sea Bottom Observatories (MSBO) and Land Stations

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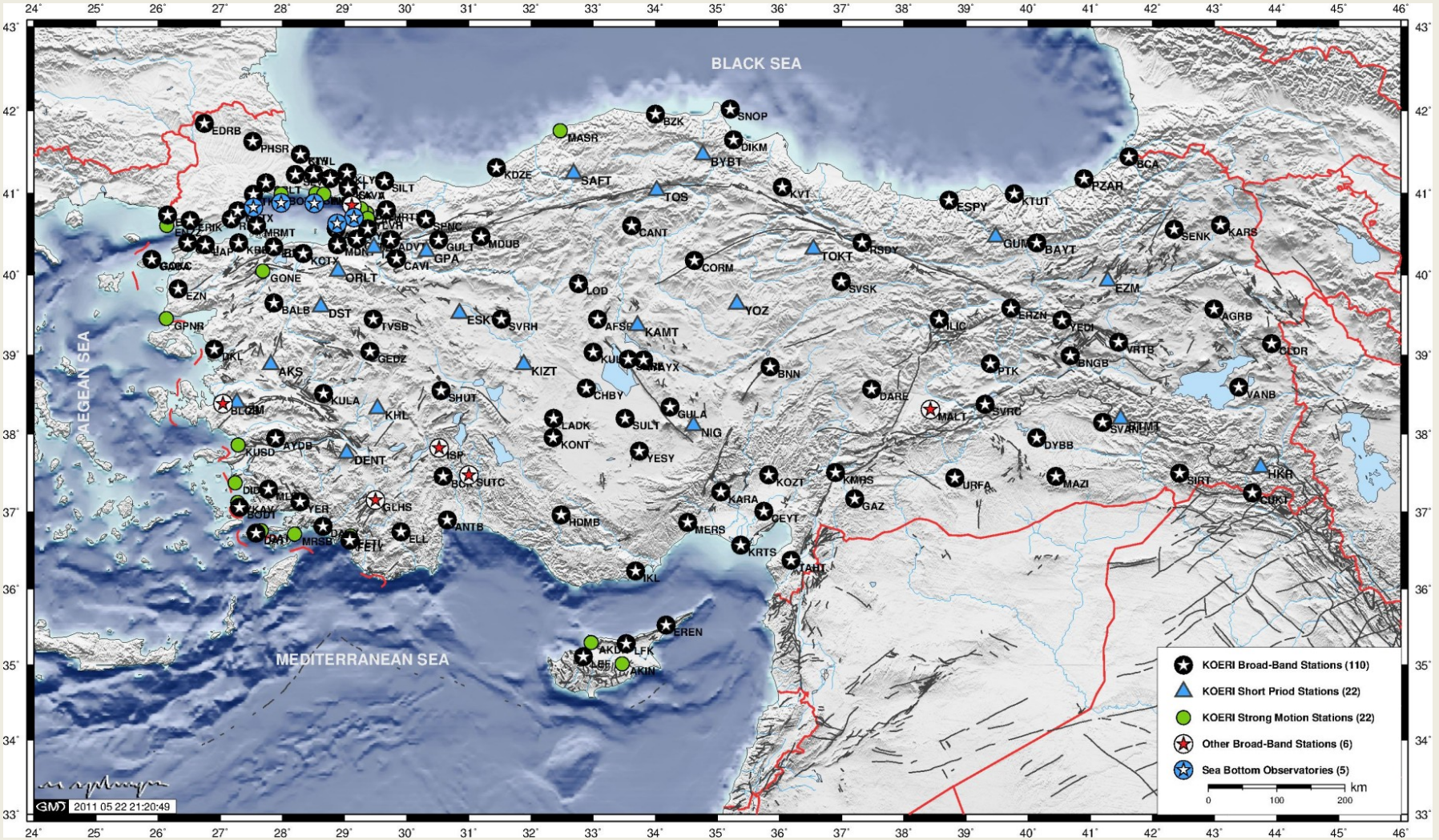
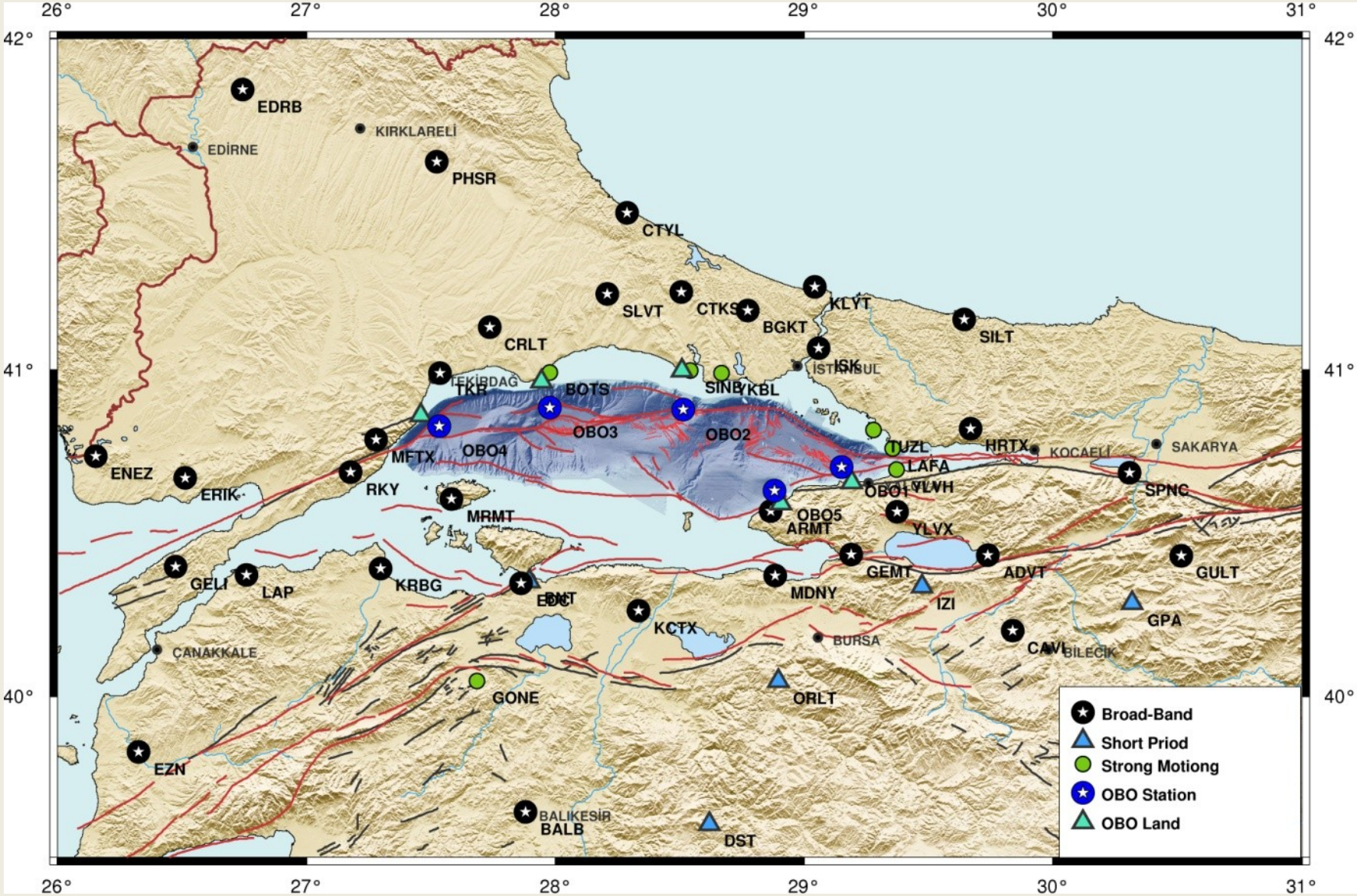
- SAMPLE APPLICATIONS FOR THE MARMARA SEA EARTHQUAKES
- CONCLUSIONS

KOERI SEISMIC NETWORK



Seismic Stations At The Marmara Region



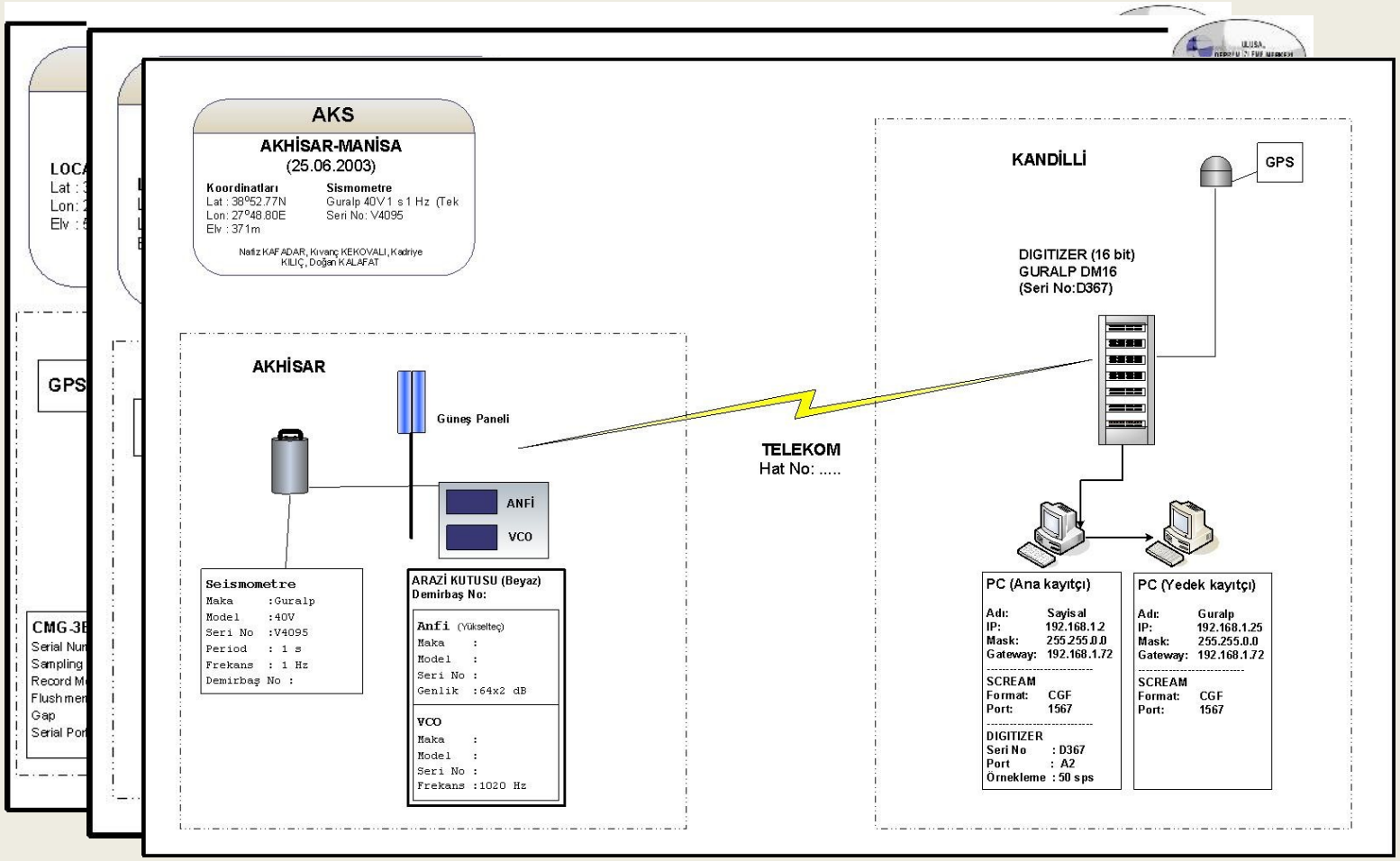
Components of KOERI Seismic Network

Land Stations				
Sensor type	*Brand*	*Period (s)*	*SPS*	*Number*
Weak Motion (BB)	CMG-3T	30-360	50-100	110
Weak Motion (SP)	?		50	22
Strong Motion	CMG-5T		100	22

Sea Bottom Observatories				
Sensor type	*Brand*	*Period (s)*	*SPS*	*Number*
Weak Motion (BB)	CMG-3T	120	100	5
Strong Motion	CMG-5T	-	100	5
Hydrophone			100	5
Pressuremeter (DPG)			100	5
Temperature prob			10	5
Flowmeter			10	5

DATA COMMUNICATION

VSAT (Most of the BB stations and some of the SM stations)
GPRS-3G (Most of the SM stations)
GPRS-EDGE (Some of the BB stations)
Leased Line (All SP stations)



DATA PROCESSING

List of Softwares used at KOERI

- zSacWin (KOERI, EQ Processing software)
- SC3 (GFZ, Real time EQ Processing software)
- Earhworm (ISTI, EQ Processing software)
- ELER (KOERI, Real time shake mapping software)
- Nami-Dance (Yalciner, Tsunami Modelling)
- SEISAN (Havskov, Off-line Processing)
- NLLOC (Lomax, 3D location)

Processing Softwares

Earhtworm

- Temporary Storage
- Converter
- Event Detection

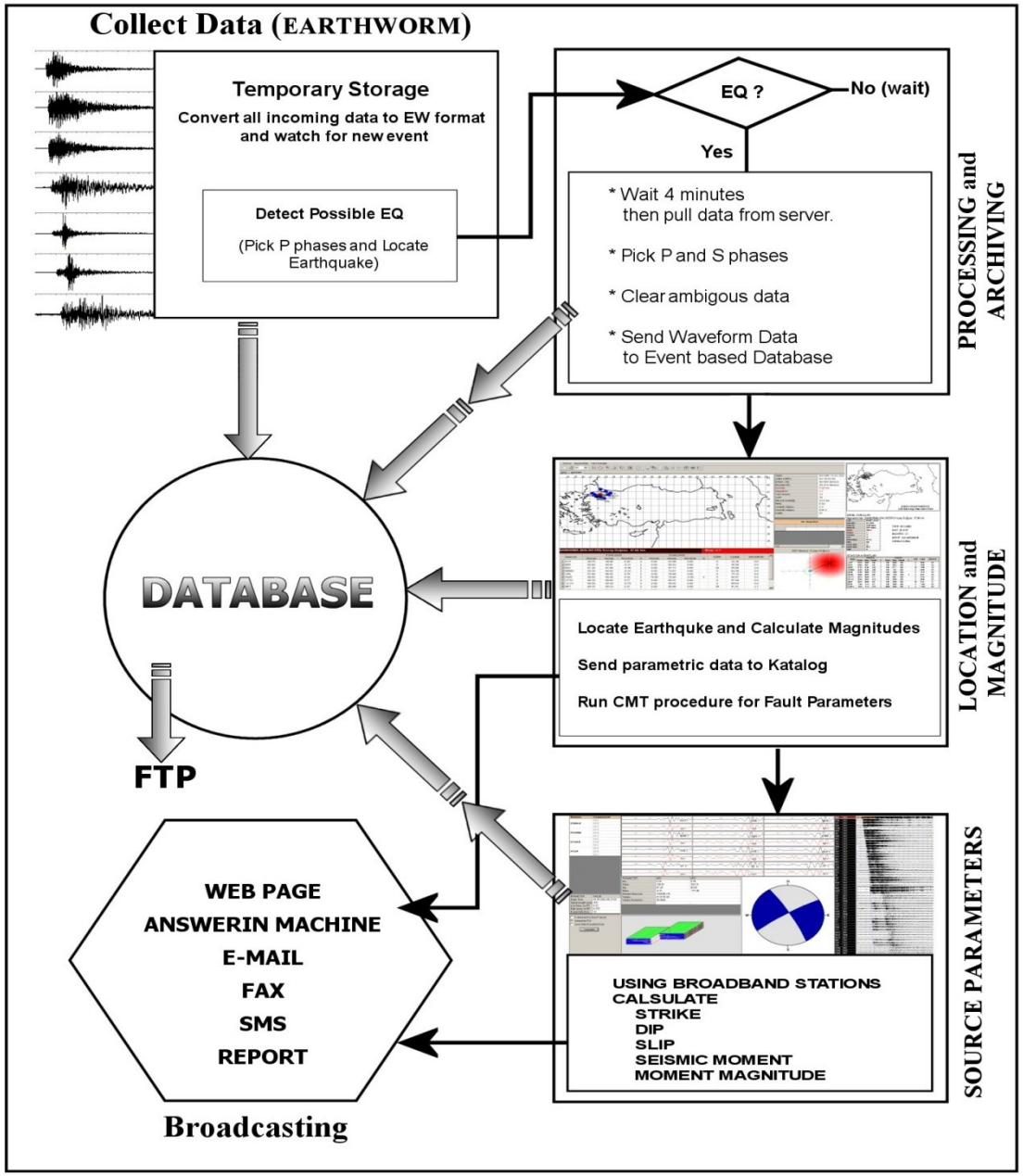
zSacWin

- EQ Processing
- Broadcasting
- Web Page
- SMS
- Answering Machine
- e-Mail
- Fax
- CB-Radio

SeisComp3 (Automatic EQ processing)

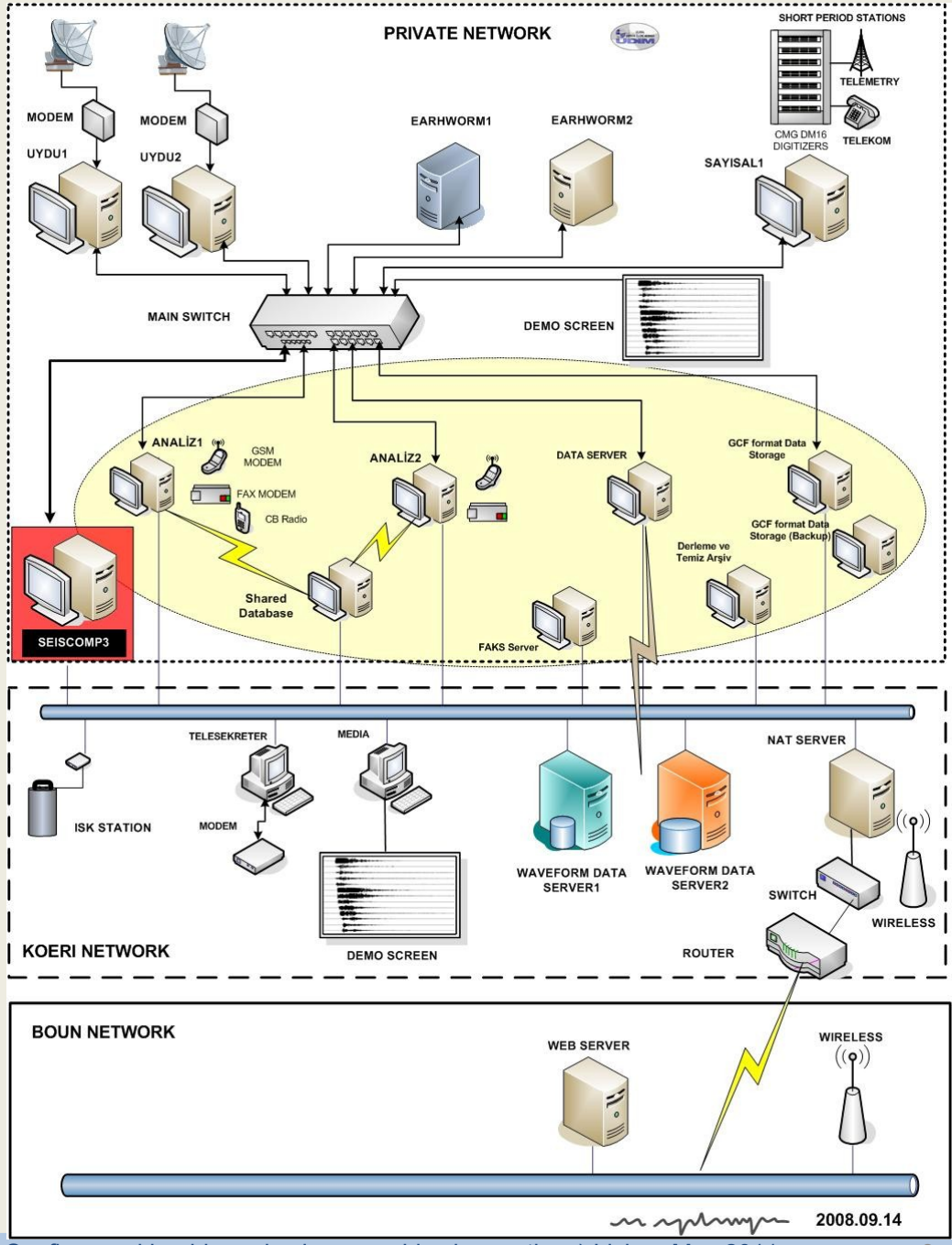
Nami-DANCE (Tsunami Modelling)

SEISAN (Off-line processing)

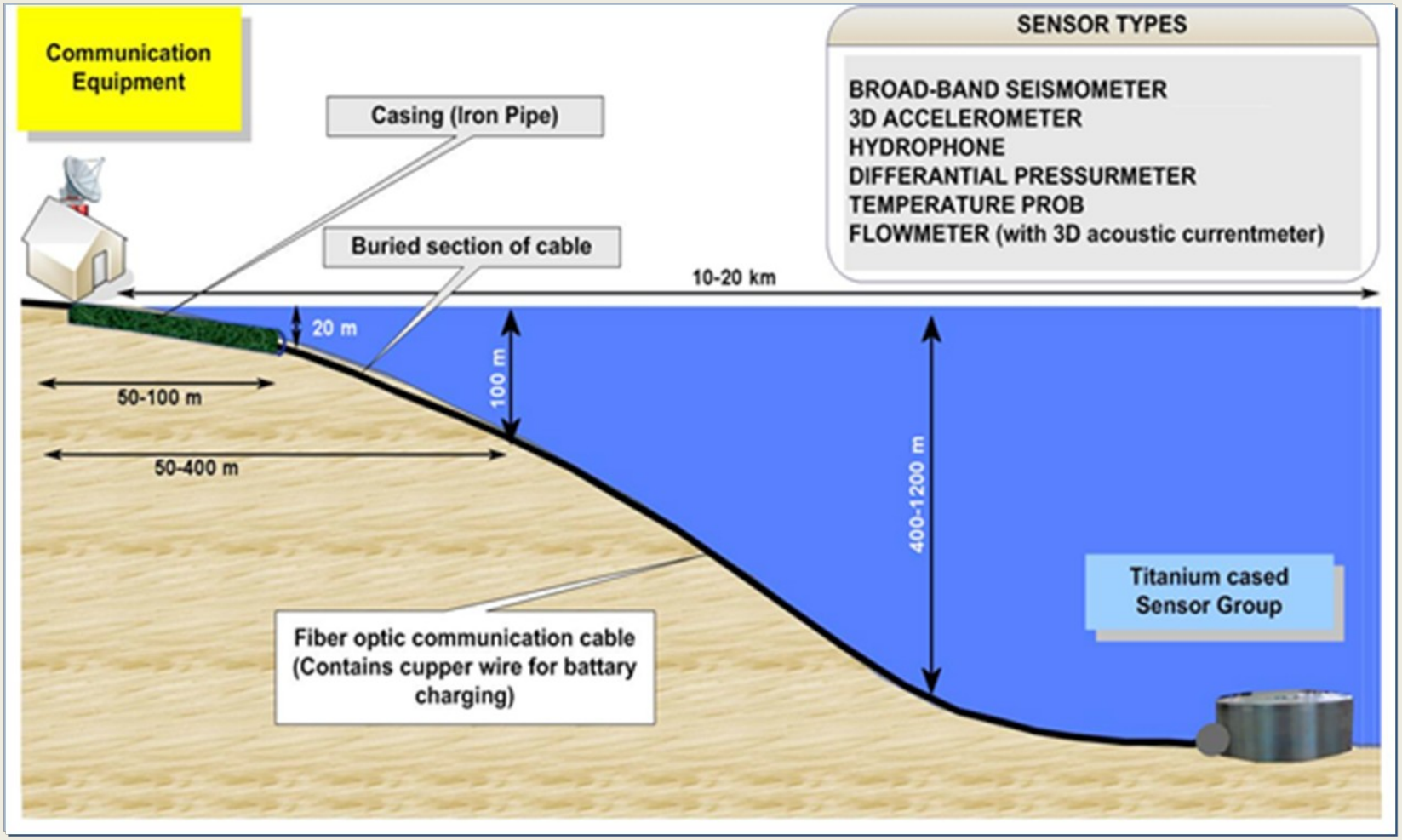


Processing Infrastructure

- **Acquisition Machines (6)**
  - Uydu (3)
  - 3G/EDGE (1) VPN
  - Leased Line (1)
  - Internet (1)
- **Earhworm Server (2)**
- **Processing Machines (6)**
  - zSacWin (2+1)
  - SeisComp3 (1+1)
  - Tsunami Modelling(1)
- **Waveform Data Storage (6)**
  - Data Preparation (1) {4 TB}
  - Data Distribution (2) {8 TB}
  - GCF Storage (2) {8 TB}
  - BLUE-RAY (1) {12 TB}
- **Data exchange (2)**

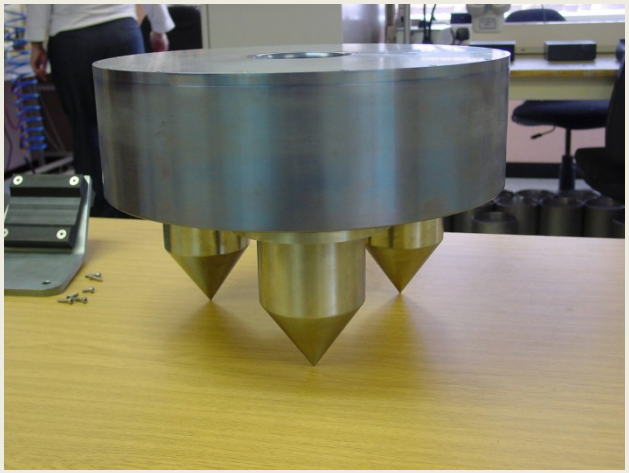


INSTALLATION OF SEA BOTTOM OBSERVATORIES



Connection to land transmission site

Components of SBO stations



CMG-3T broadband 120 sec velocity seismometer.

CMG-5T low noise feedback accelerometer.

Differential pressure transducer (DPG)

Hydrophone interfaced to one of the 24 bit digitiser.

High resolution temperature probe interfaced to an environmental channel.

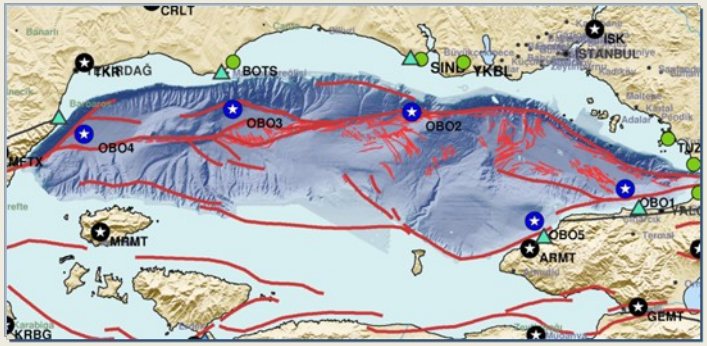
Flow meter with 3D Acoustic current meter.

Power management system to be operated via cabling.

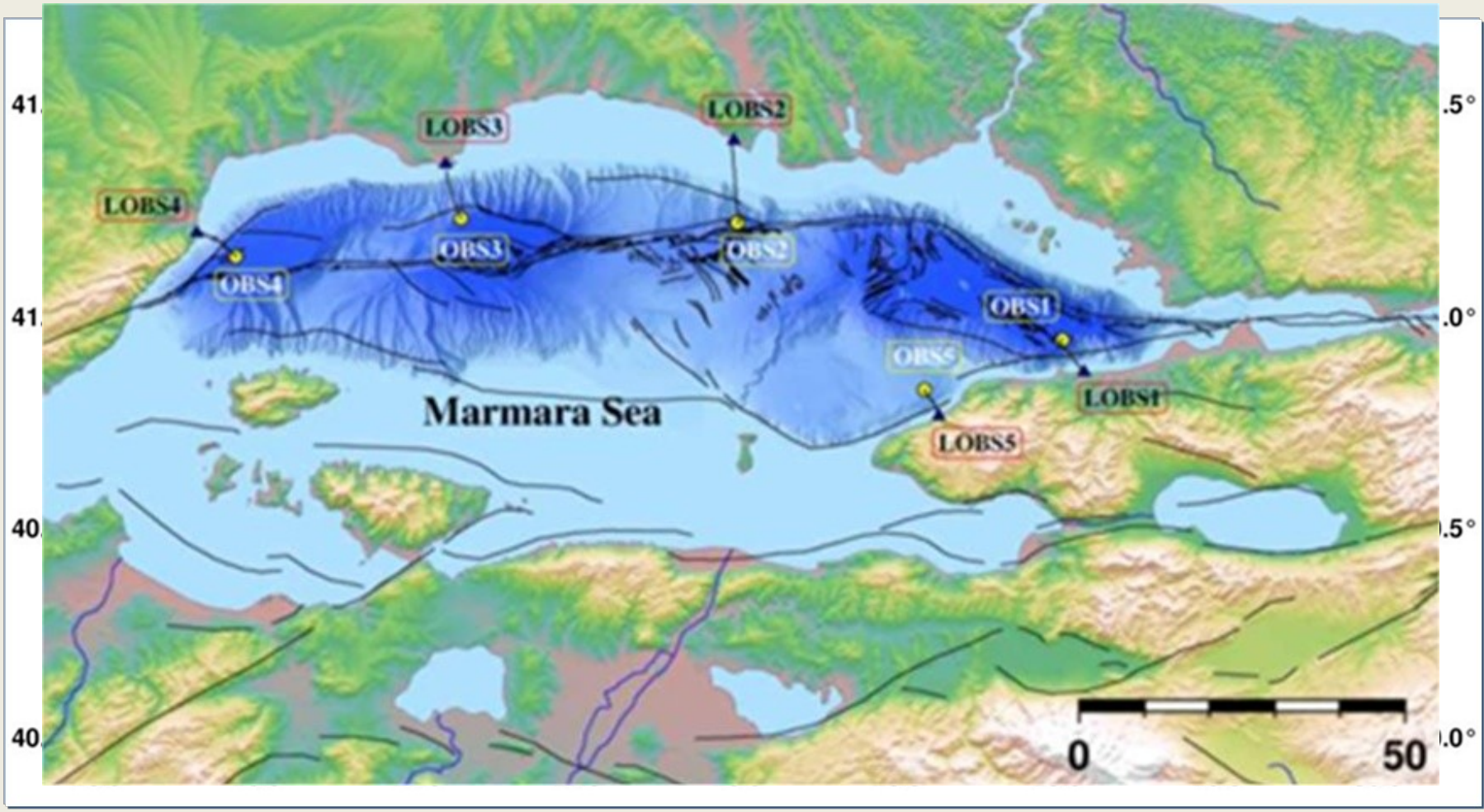
There is a redundancy in the cabling such that in the event of any optical line failure, there are further 4 redundant optical lines.

Location information of Sea-bottom observatories

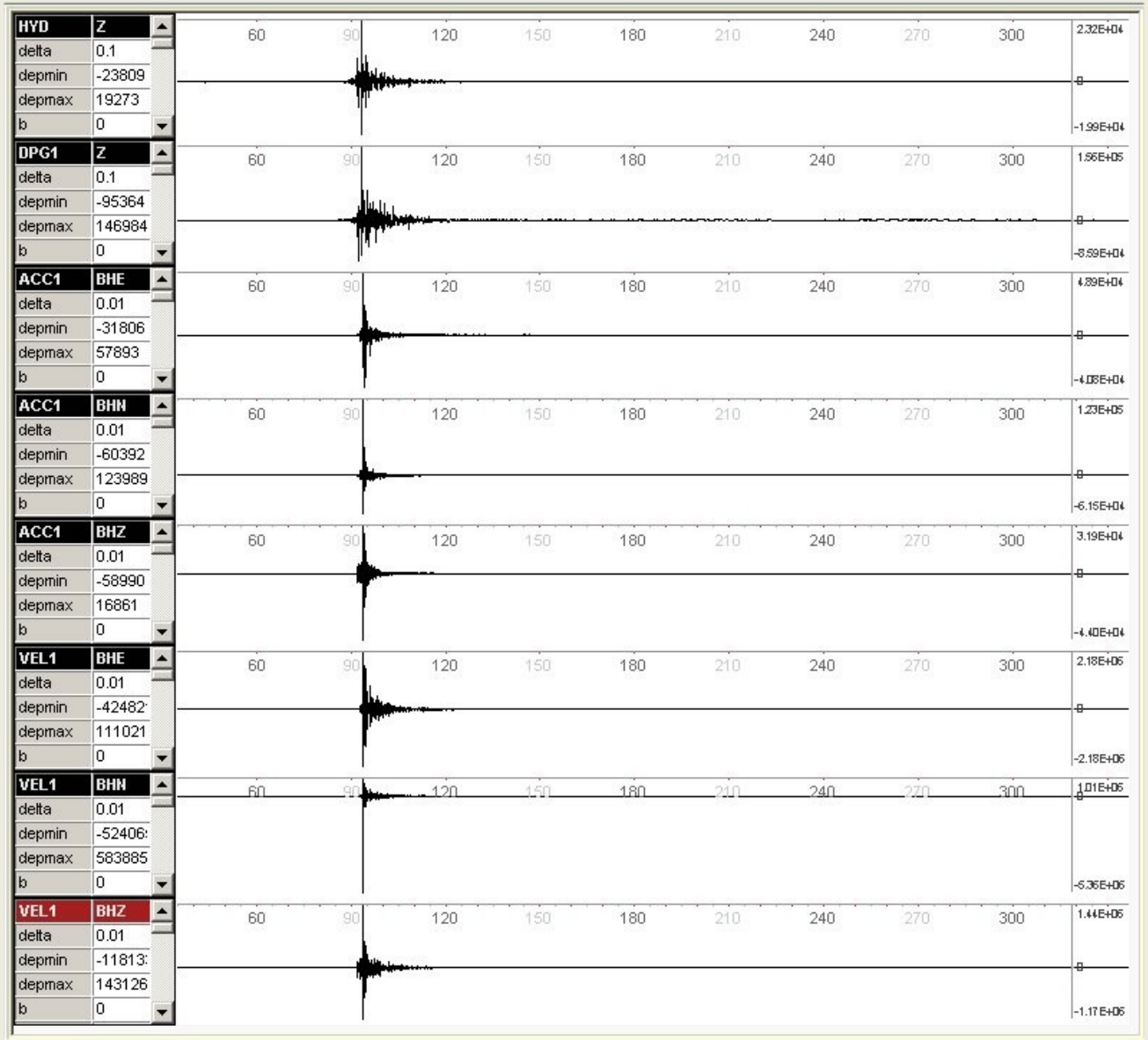
Station		Lat (°)	Lon (°)	Cable lenght (m)	Instal. Date	Depth (m)	Azimuth
OBO-1	Sea	40.705638	29.149183	10000	31.12.2010	1260	156.7°
	Land	40.657299	29.191900				
OBO-2	Sea	40.878619	28.514247	16000	03.11.2010	810	23.8°
	Land	40.999814	28.507368				
OBO-3	Sea	40.884783	27.975100	12000	21.01.2011	1204	308.7°
	Land	40.965266	27.944733				
OBO-4	Sea	40.828184	27.535460	10000	22.12.2010	1144	260.0°
	Land	40.862821	27.459275				
OBO-5	Sea	40.631132	28.880385	9000	09.06.2010	368	192.2°
	Land	40.591945	28.907368				



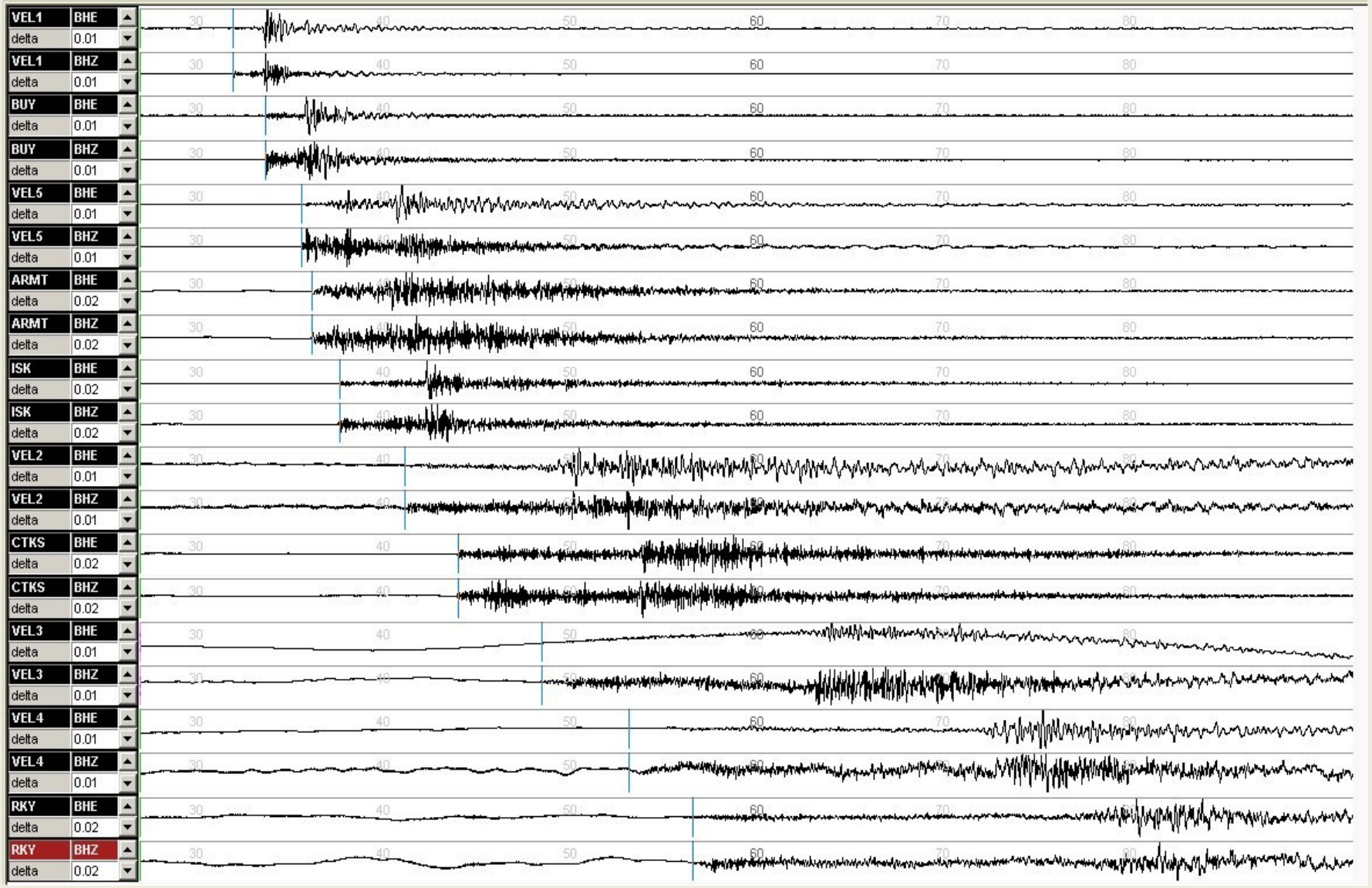
Location map of Sea-bottom observatories



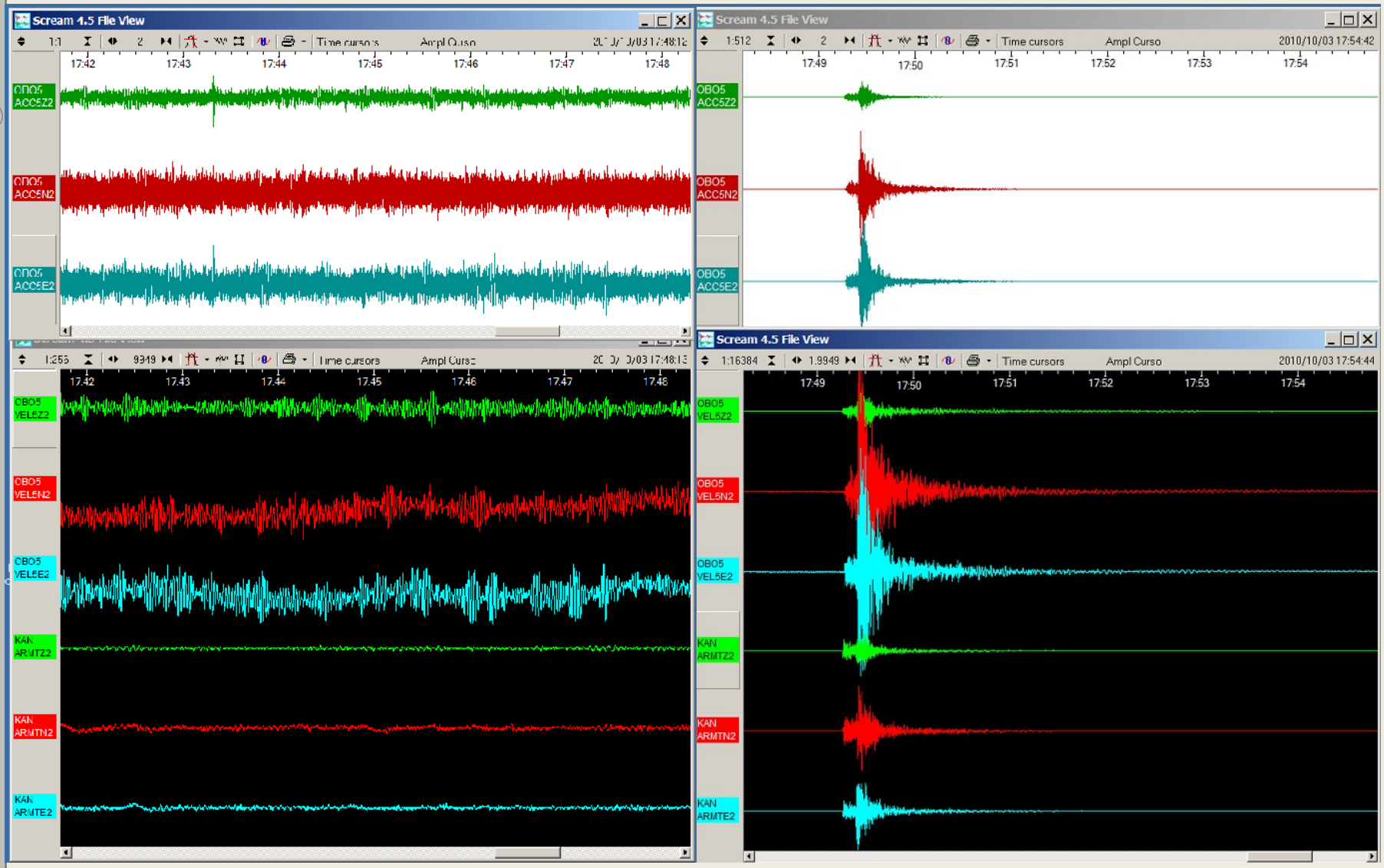
Sample record: SBO1 (All sensors)



Sample record: All SBO BBs with land stations



Sample record: Noise and Event



Noise spectrum of Land and SBO stations (08.02.2011- 01:00)

No earthquake

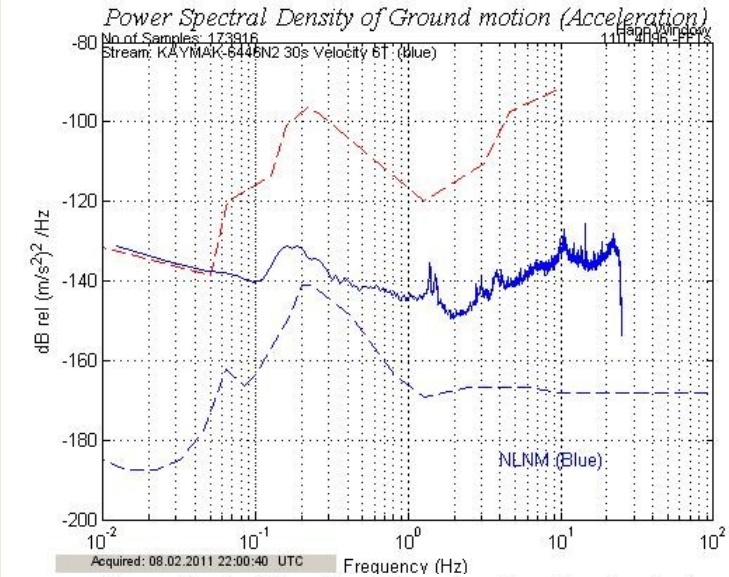
Noise spectrum of KAYMAK and KRMRS Land stations (08.02.2011- 01:00)

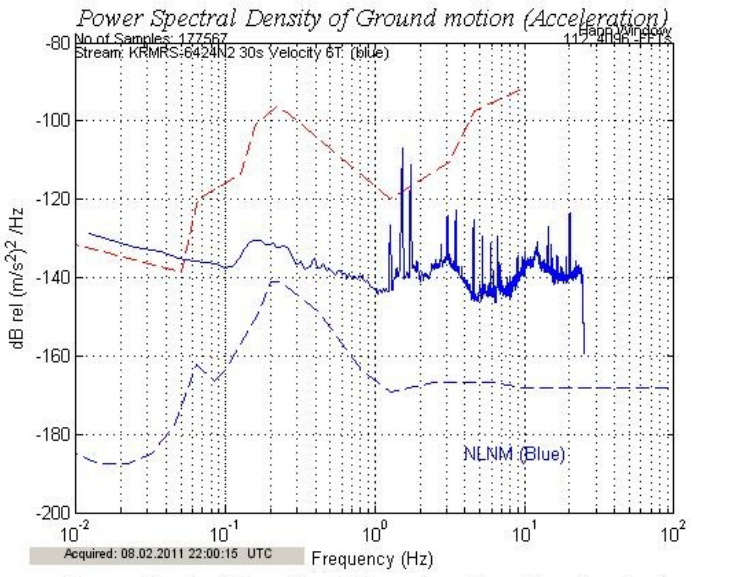
KAYMAK

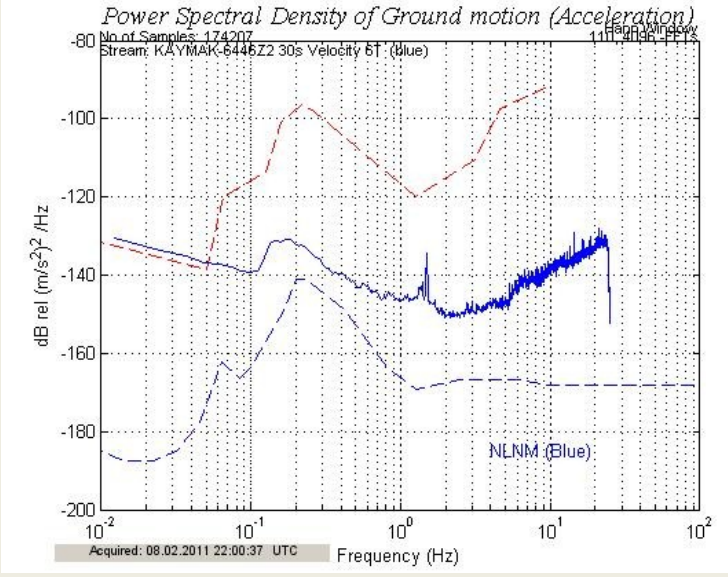
KRMRS

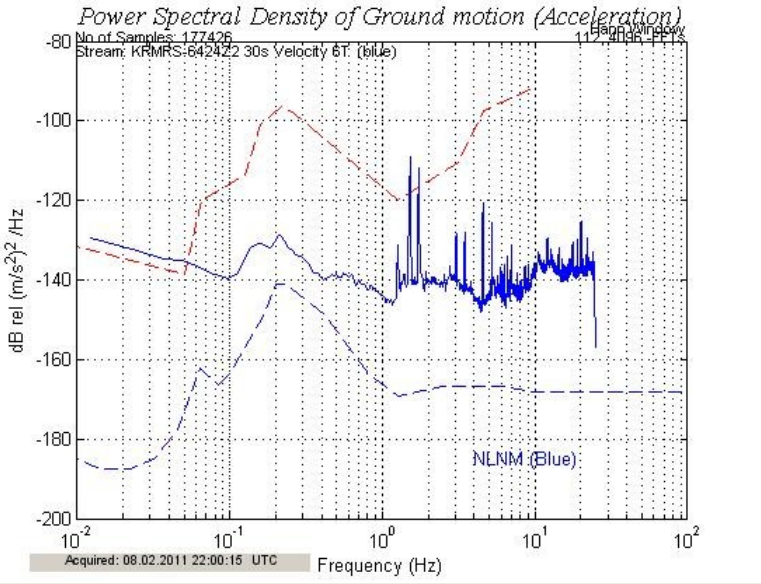
N-S Comp

Z Comp







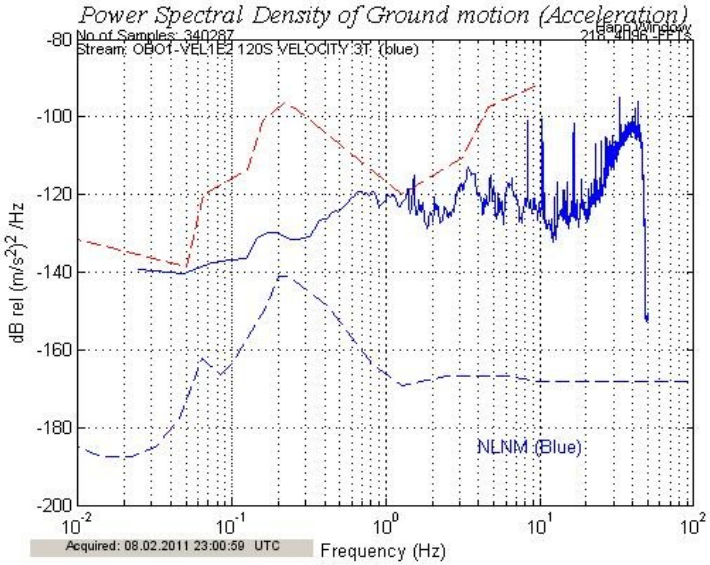


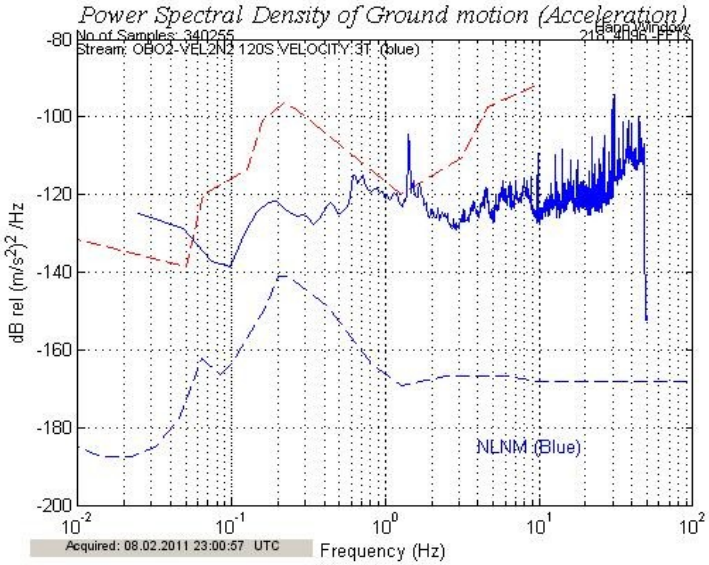
Noise spectrum of SBO stations (08.02.2011- 01:00 Hours)

OBO1

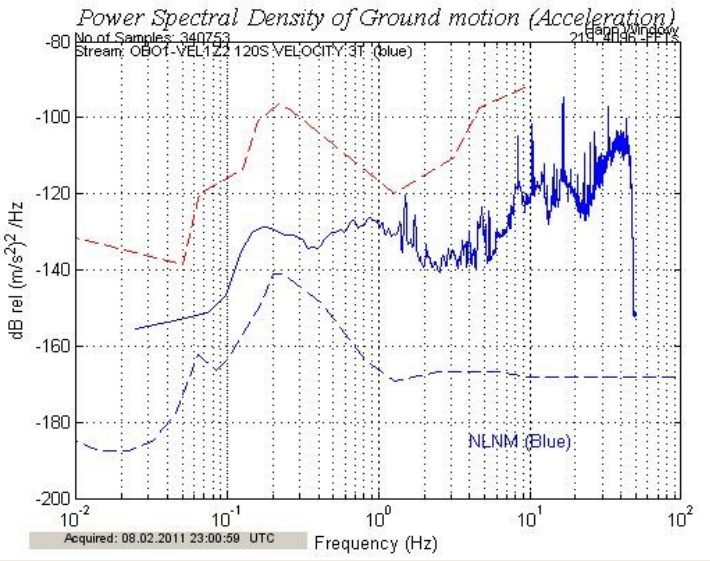
OBO2

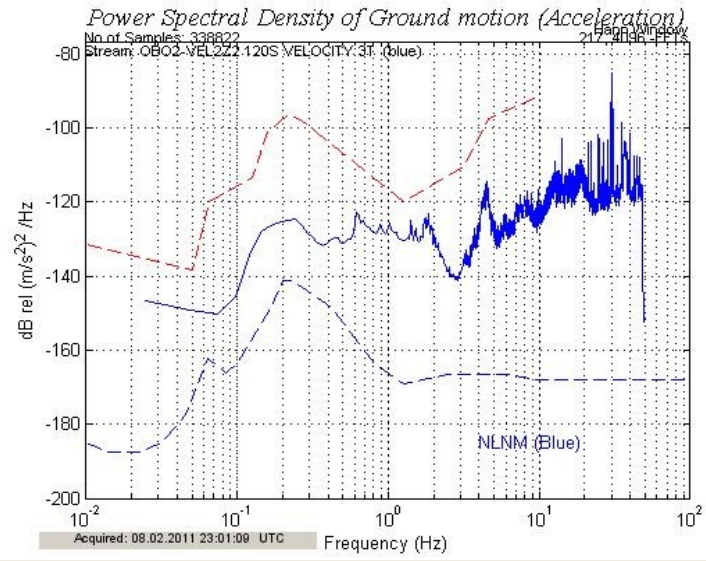
Horizontal Comp.





Vertical Comp.

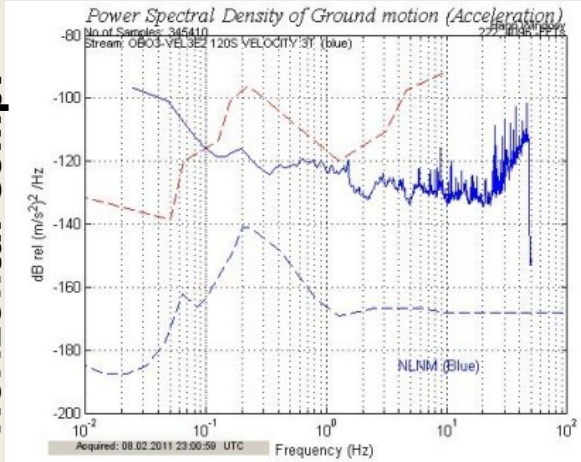


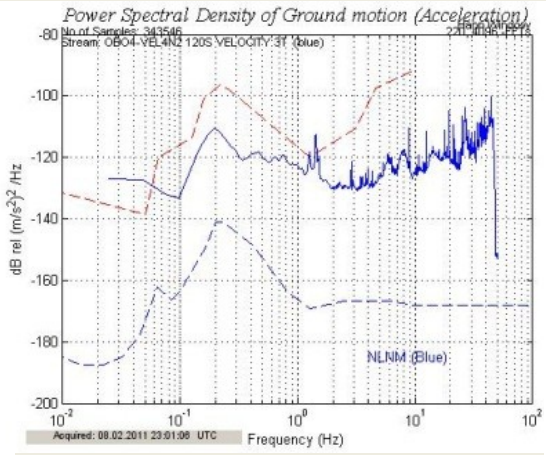


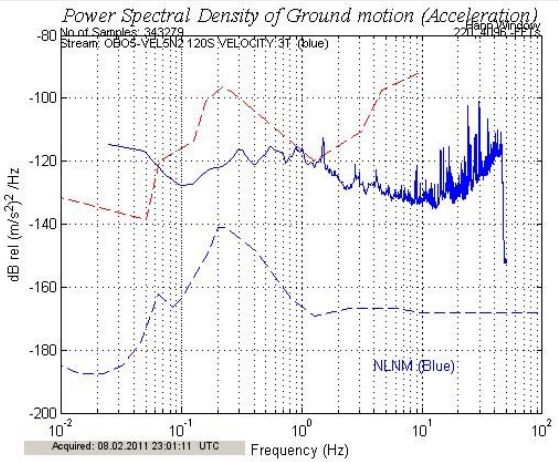
Noise spectrum of SBO stations (08.02.2011- 01:00 Hours) *Cont.*

OBO3 **OBO4** **OBO5**

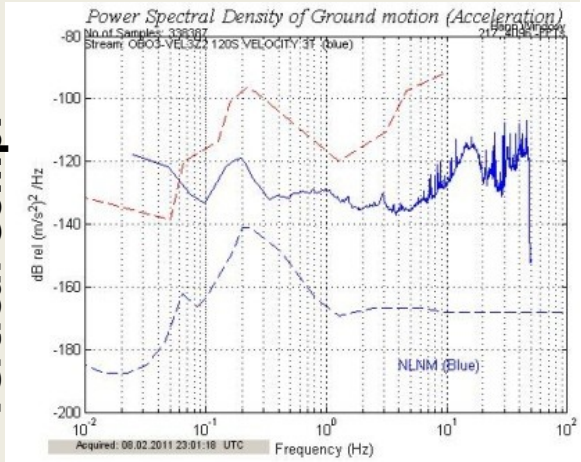
Horizontal Comp.

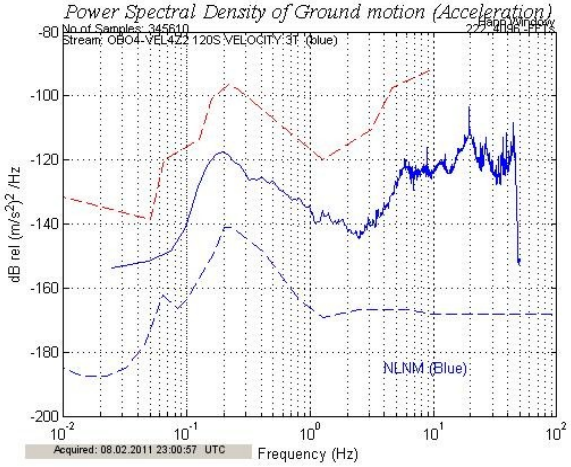


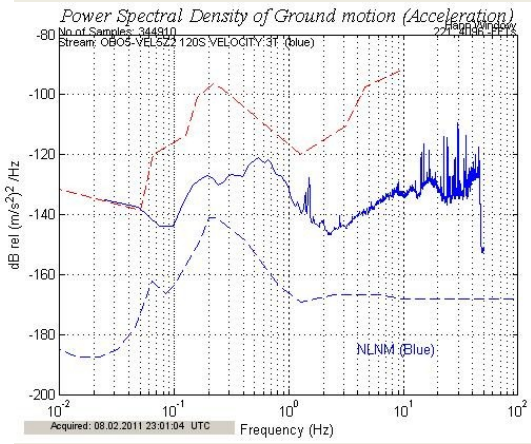




Vertical Comp.







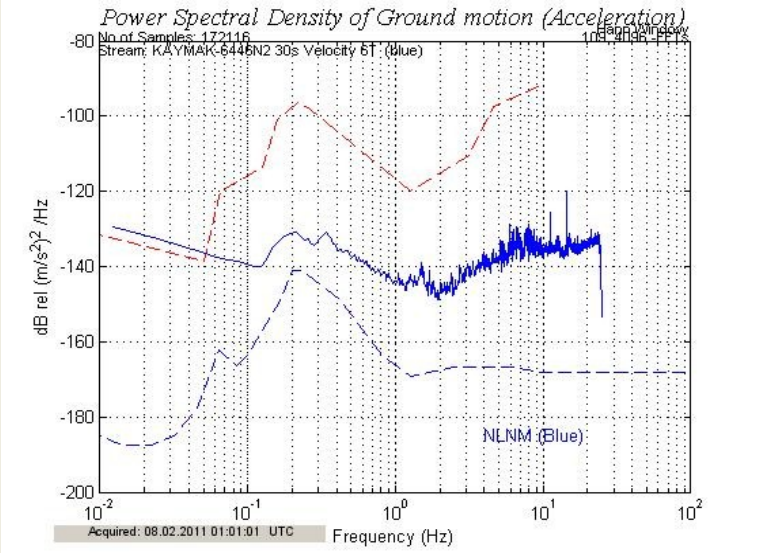
Spectrum of (2011.02.08 01:56:38; M=2.7) earthquake recorded at Land and SBO stations

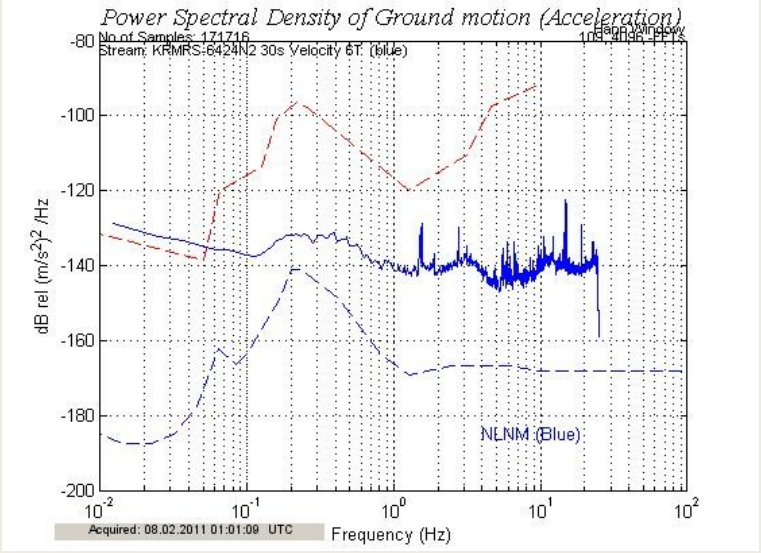
Specrum of (2011.02.08 01:56:38; M=2.7) earthquake recorded at KAYMAK and KRMRS land stations

KAYMAK

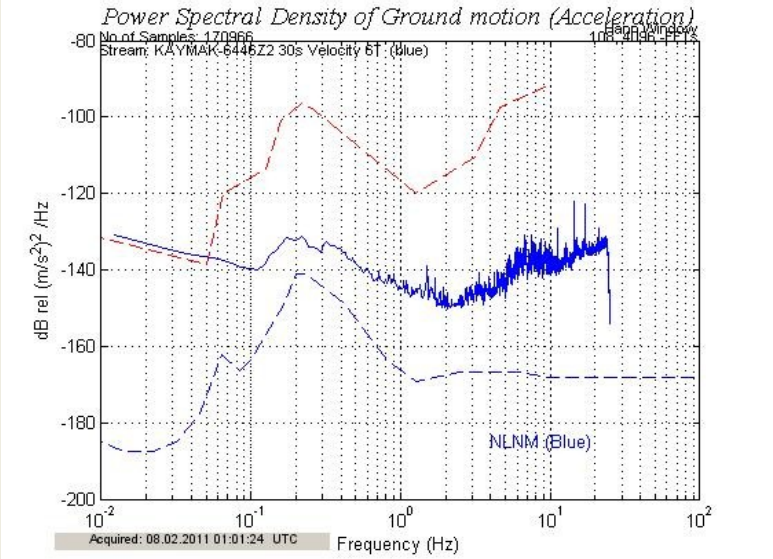
KRMRS

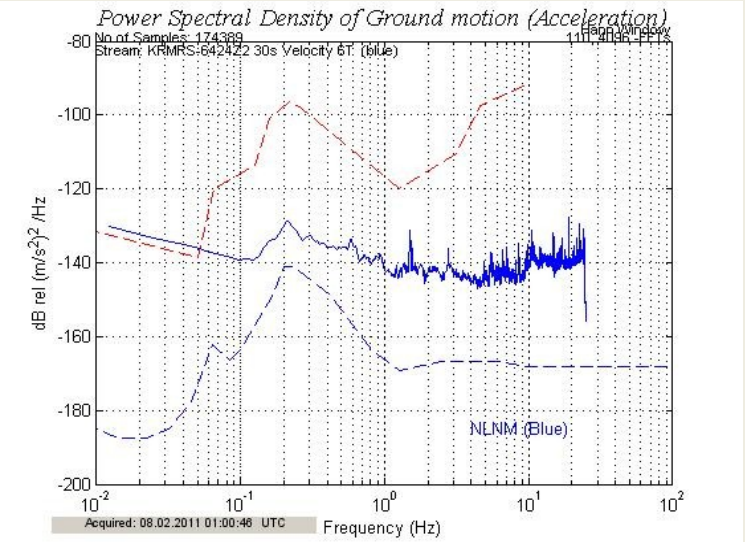
Horizontal Comp.



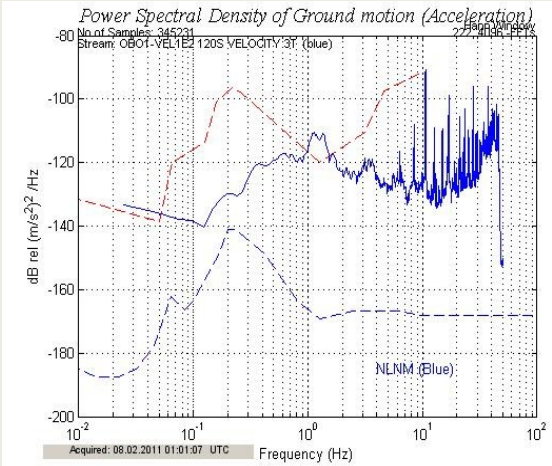
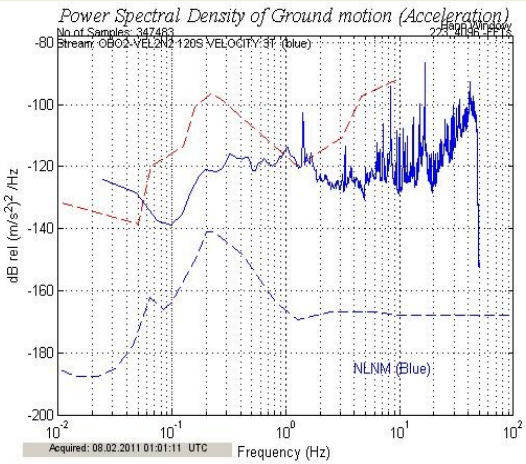
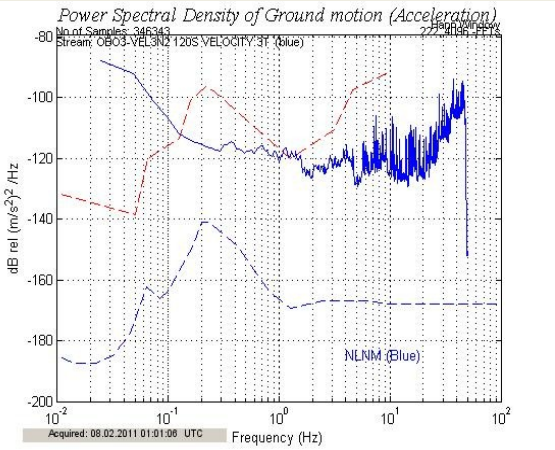
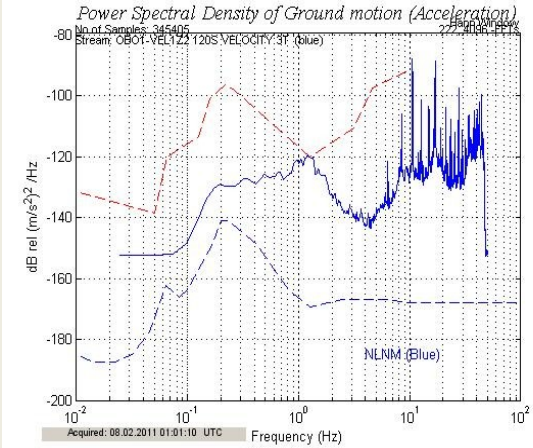
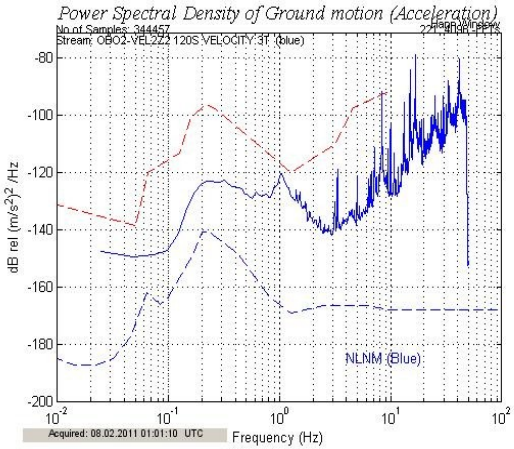
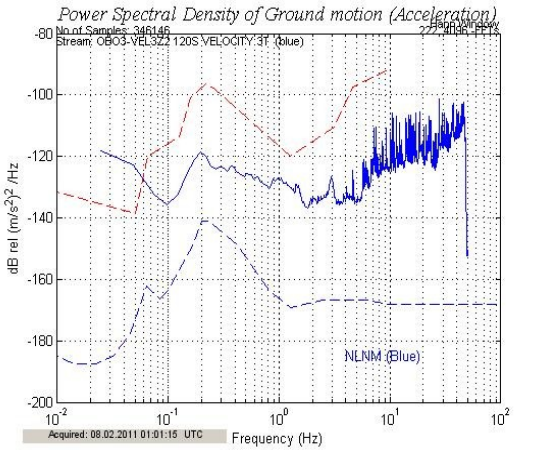


Vertical Comp.





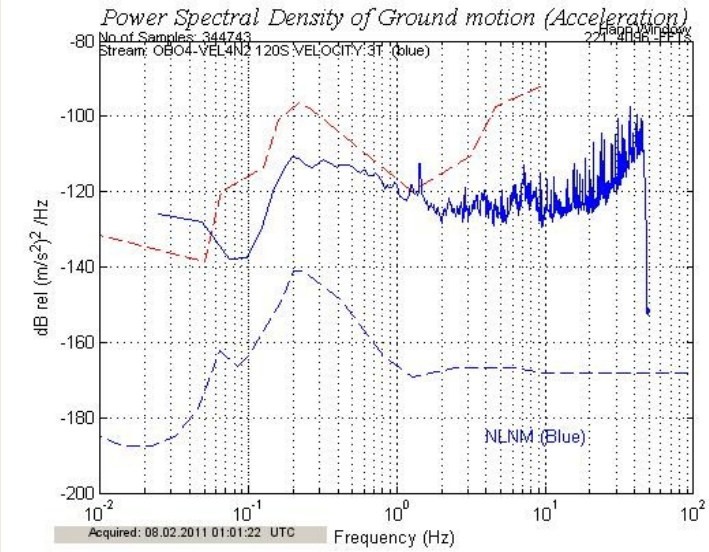
Specrum of (2011.02.08 01:56:38; M=2.7) earthquake recorded at SBO stations

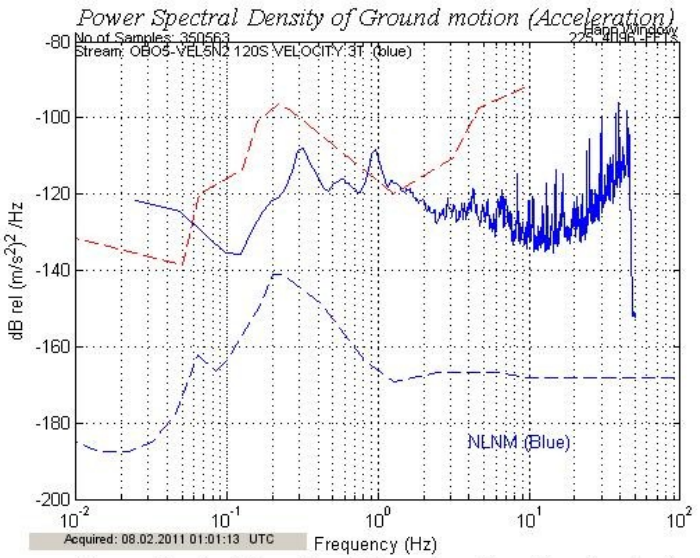
	OBO1	OBO2	OBO2
Horizontal Comp.			
Vertical Comp.			

Specrum of (2011.02.08 01:56:38; M=2.7) earthquake recorded at SBO stations (cont.)

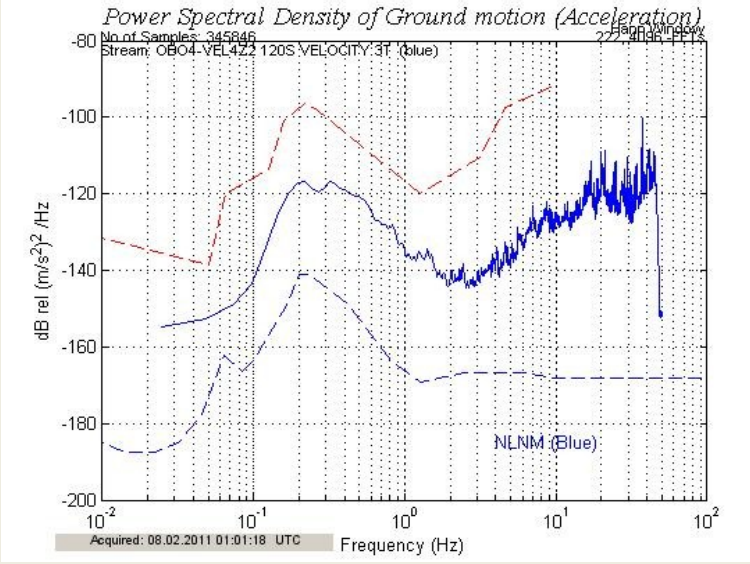
OBO4 | **OBO5**

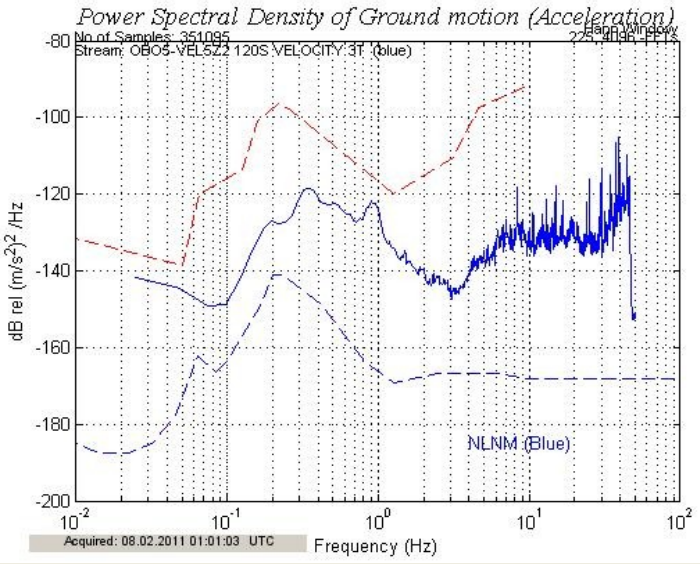
Horizontal Comp.





Vertical Comp.





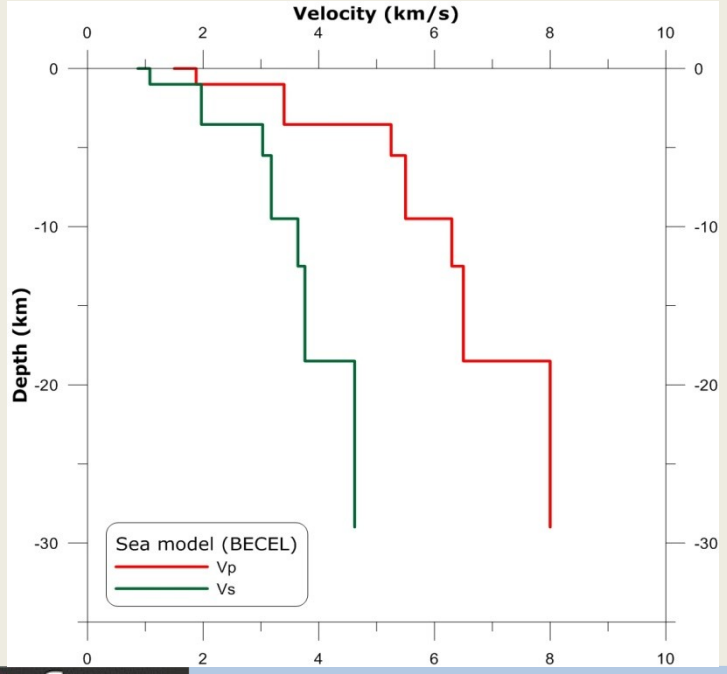
Location of Marmara Sea earthquakes using land and sea bottom observatory data

Number of located EQ : 11; Location softwares: SEISAN, NLLOC

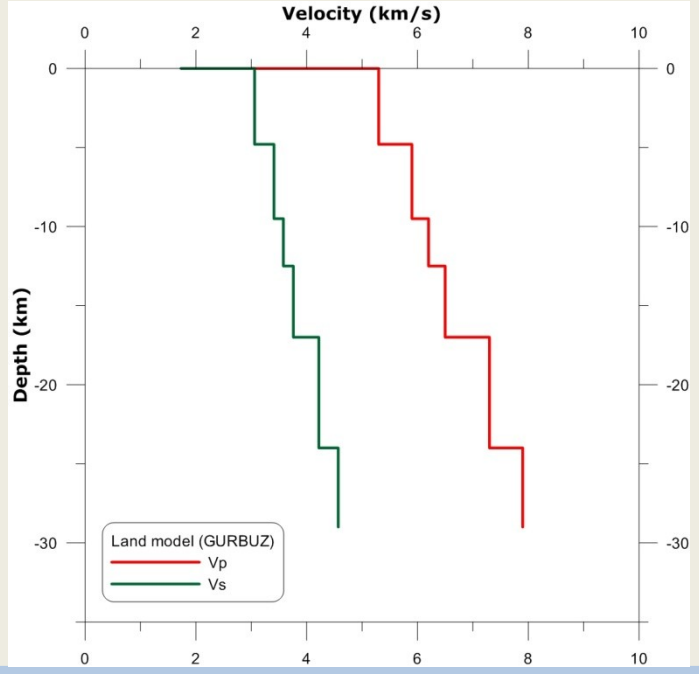
Code for Combination	*Stations*	*Model*	*Software*	*Synbol*
NOBOL	Land stations	Land model	SEISAN	**O**
	OBS stations	Land model	SEISAN	**Δ**
	OBS stations	Land model	NLLOC	*
NOBOLL	Land stations	Land model	SEISAN	**O**
	Land and OBS stations	Land model	SEISAN	**Δ**
	Land and OBS stations	Land model	NLLOC	*
NOBOLS	Land stations	Land model	SEISAN	**O**
	Land and OBS stations	Sea model	SEISAN	**Δ**
	Land and OBS stations	Sea model	NLLOC	*
NOBOS	Land stations	Land model	SEISAN	**O**
	OBS stations	Sea model	SEISAN	**Δ**
	OBS stations	Sea model	NLLOC	*
OBO	Land stations	Land model	SEISAN	**O**
	OBS stations	Land model	SEISAN	**Δ**
	OBS stations	Sea model	SEISAN	*
OBOL	Land stations	Land model	SEISAN	**O**
	Land and OBS stations	Land model	SEISAN	**Δ**
	Land and OBS stations	Sea model	SEISAN	*

Earth Models used in sample applications

SEA MODEL (BECEL)		
Depth(km)	Vp(km/s)	Vs(km/s)
0.00	1.50	0.87
1.00	1.88	1.08
3.54	3.40	1.97
5.50	5.25	3.03
9.50	5.50	3.18
12.50	6.30	3.64
18.50	6.50	3.76
29.00	8.00	4.62



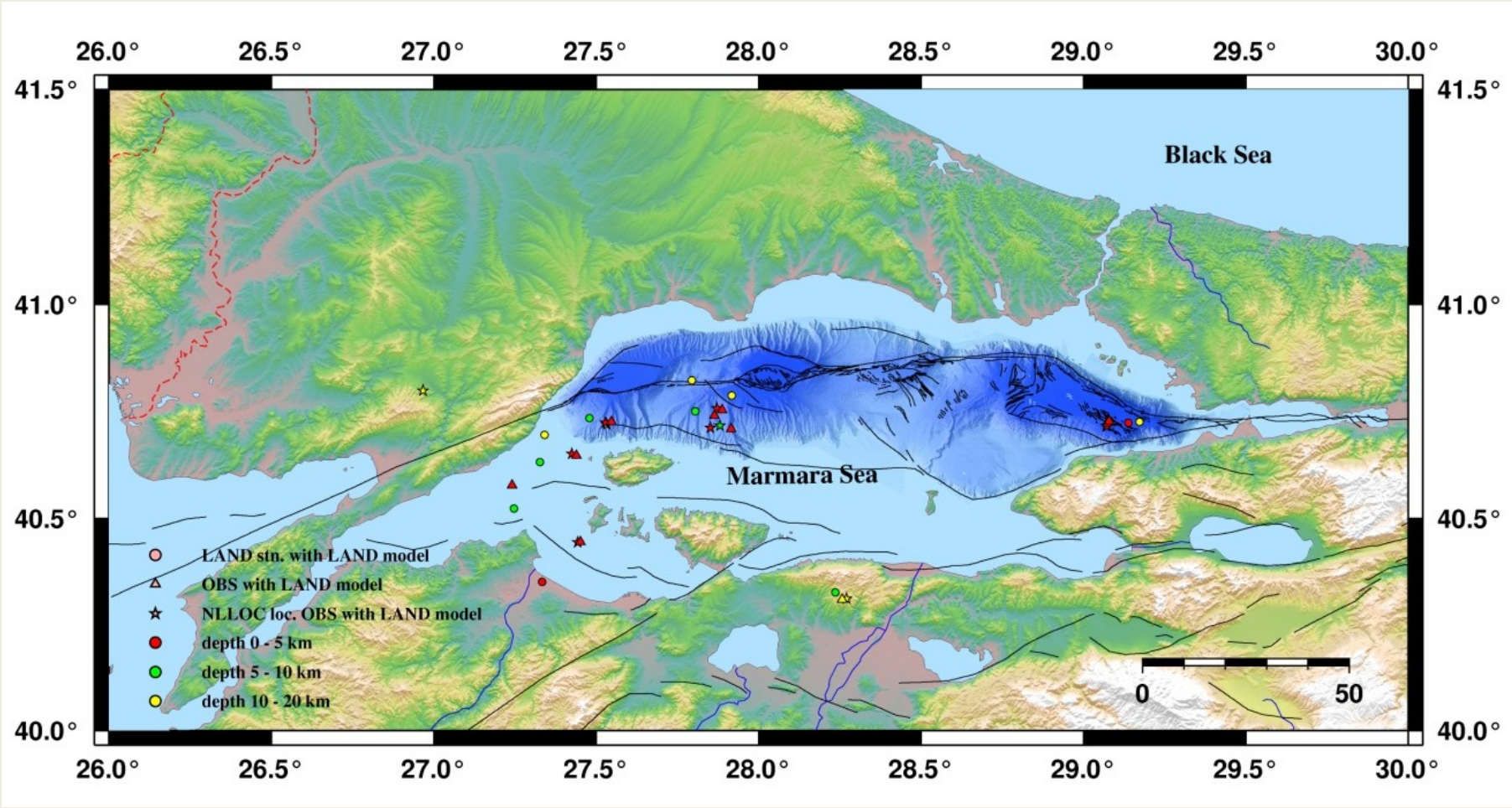
LAND MODEL (GURBUZ)		
Depth(km)	Vp(km/s)	Vs(km/s)
0.00	3.00	1.73
4.80	5.30	3.06
9.50	5.90	3.41
12.50	6.20	3.58
17.00	6.50	3.76
24.00	7.30	4.22
29.00	7.90	4.57
-	-	-



NOBOL

O location done using land stations with land model (SEISAN)
Δ location done using OBS stations land model (SEISAN)
***** location done using OBS stations land model (NLLOC)

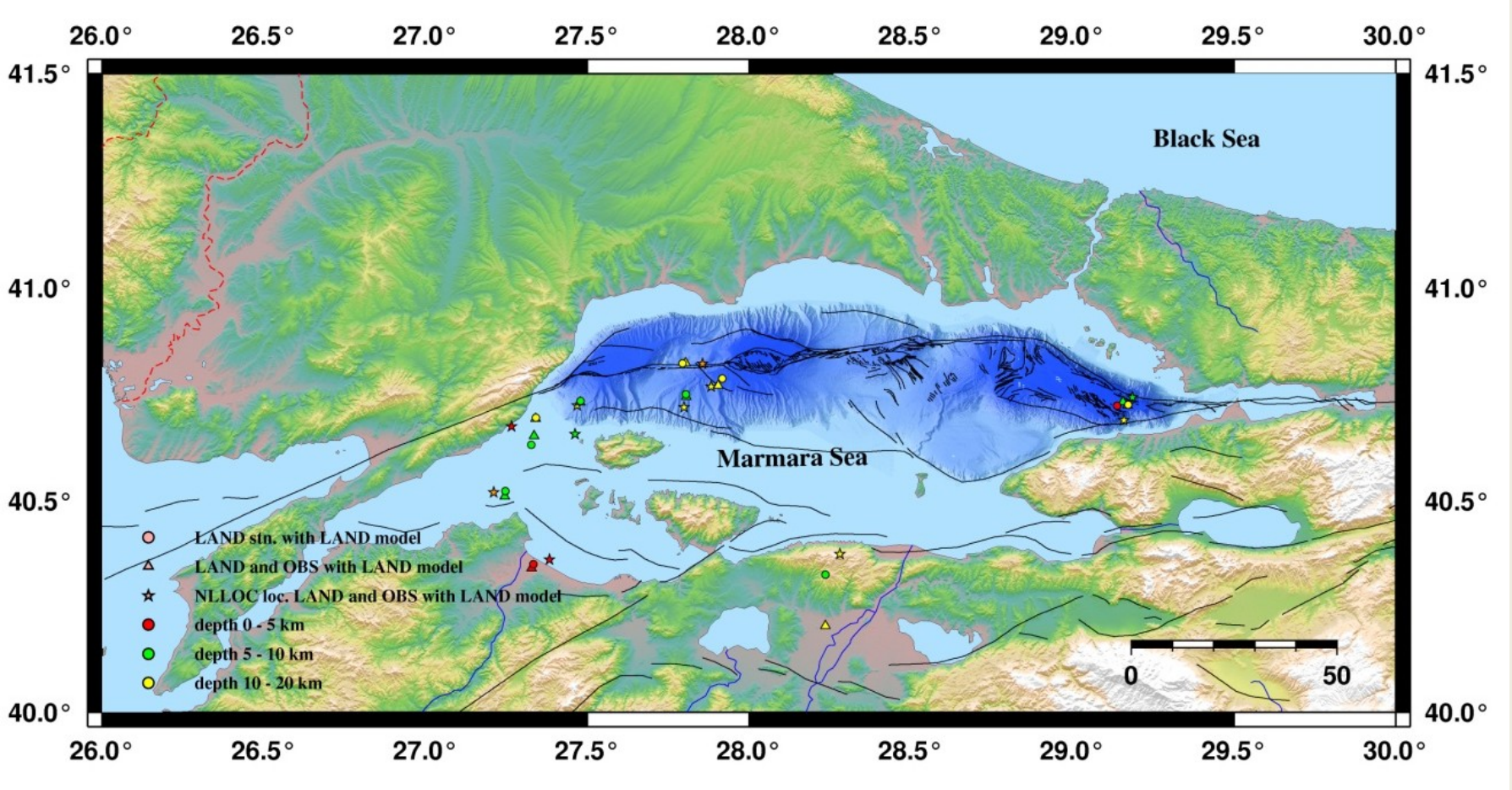
Color gives depth range of earthquakes



NOBOLL

O location done using land stations with land model (SEISAN)
Δ location done using Land and OBS stations with land model (SEISAN)
***** location done using Land and OBS stations with land model (NLLOC)

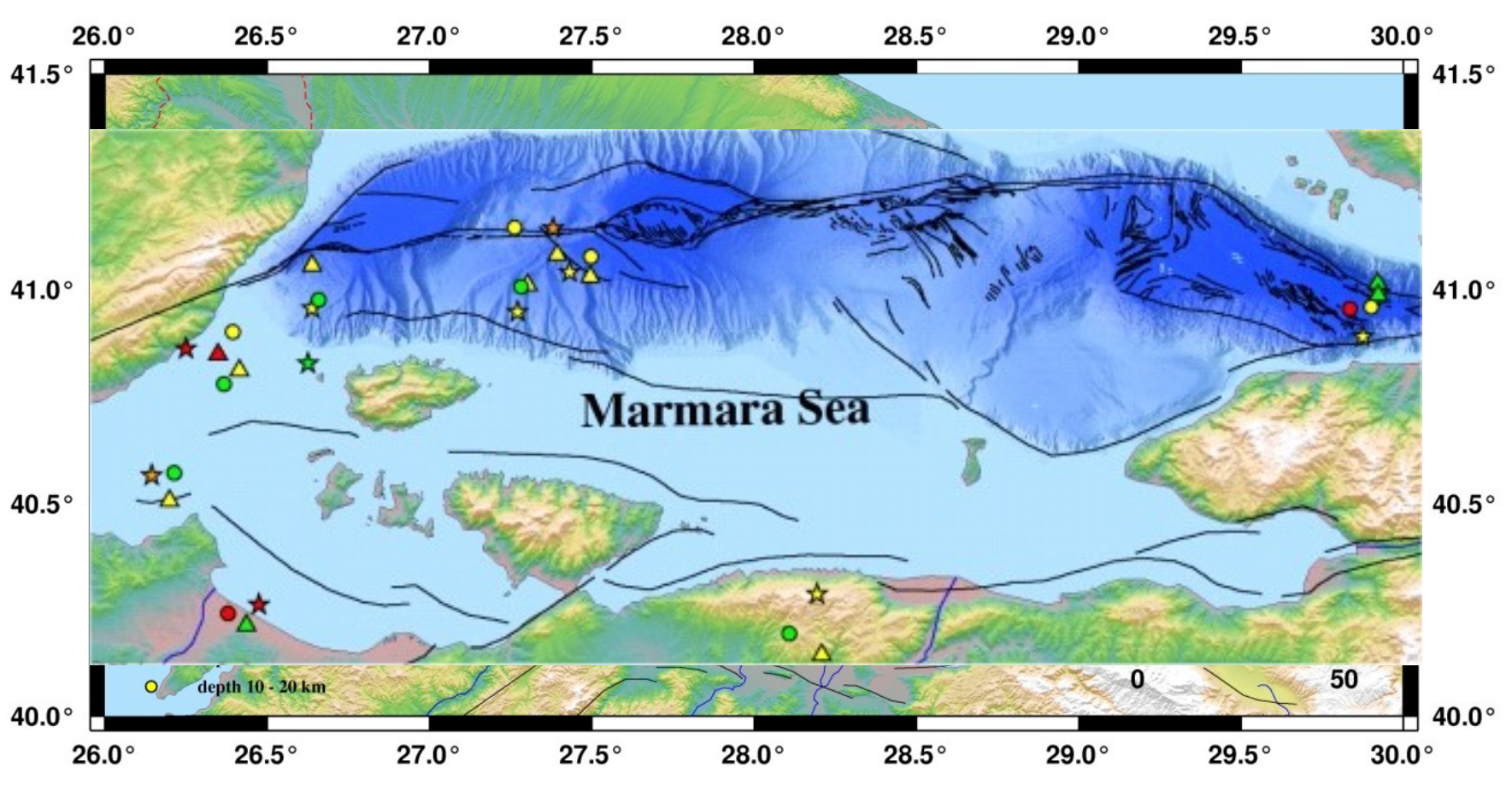
Color gives depth range of earthquakes



NOBOLS

O location done using land stations with land model (SEISAN)
Δ location done using Land and OBS stations with sea model (SEISAN)
***** location done using Land and OBS stations with sea model (NLLOC)

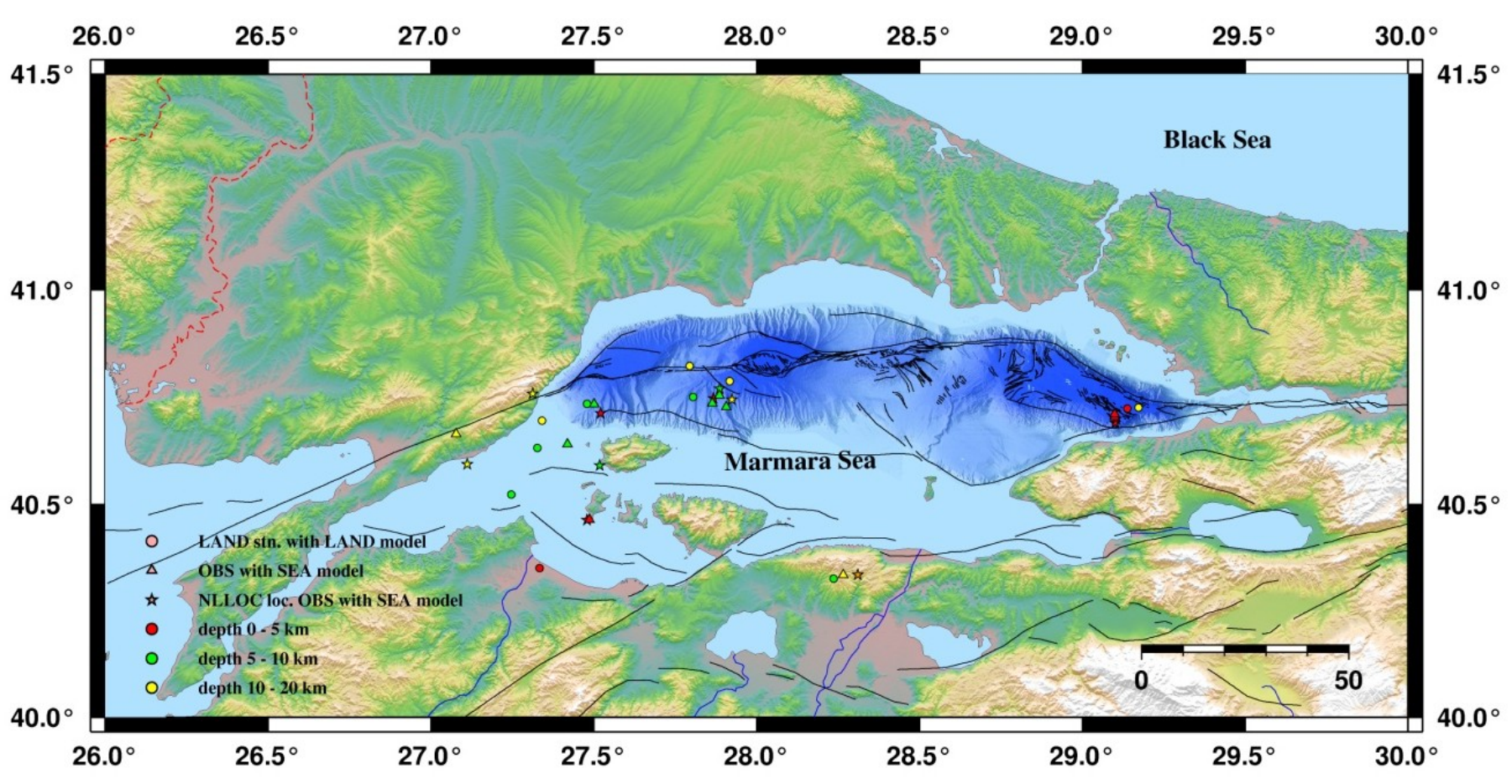
Color gives depth range of earthquakes



NOBOS

O location done using land stations with land model (SEISAN)
Δ location done using OBS stations with sea model (SEISAN)
***** location done using OBS stations with sea model (NLLOC)

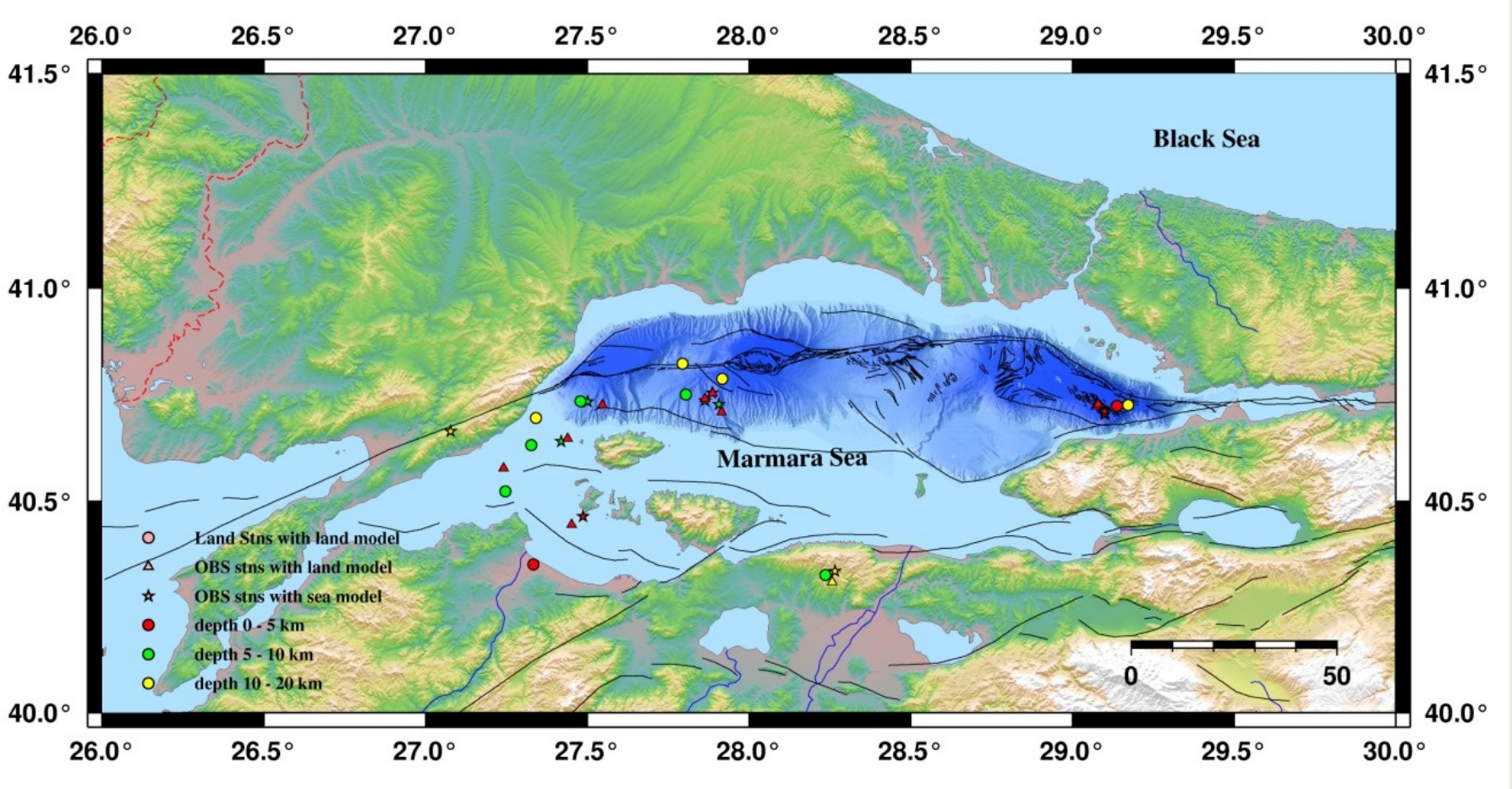
Color gives depth range of earthquakes



OBO

O location done using land stations with land model (SEISAN)
Δ location done using OBS stations with land model (SEISAN)
***** location done using OBS stations with sea model (SEISAN)

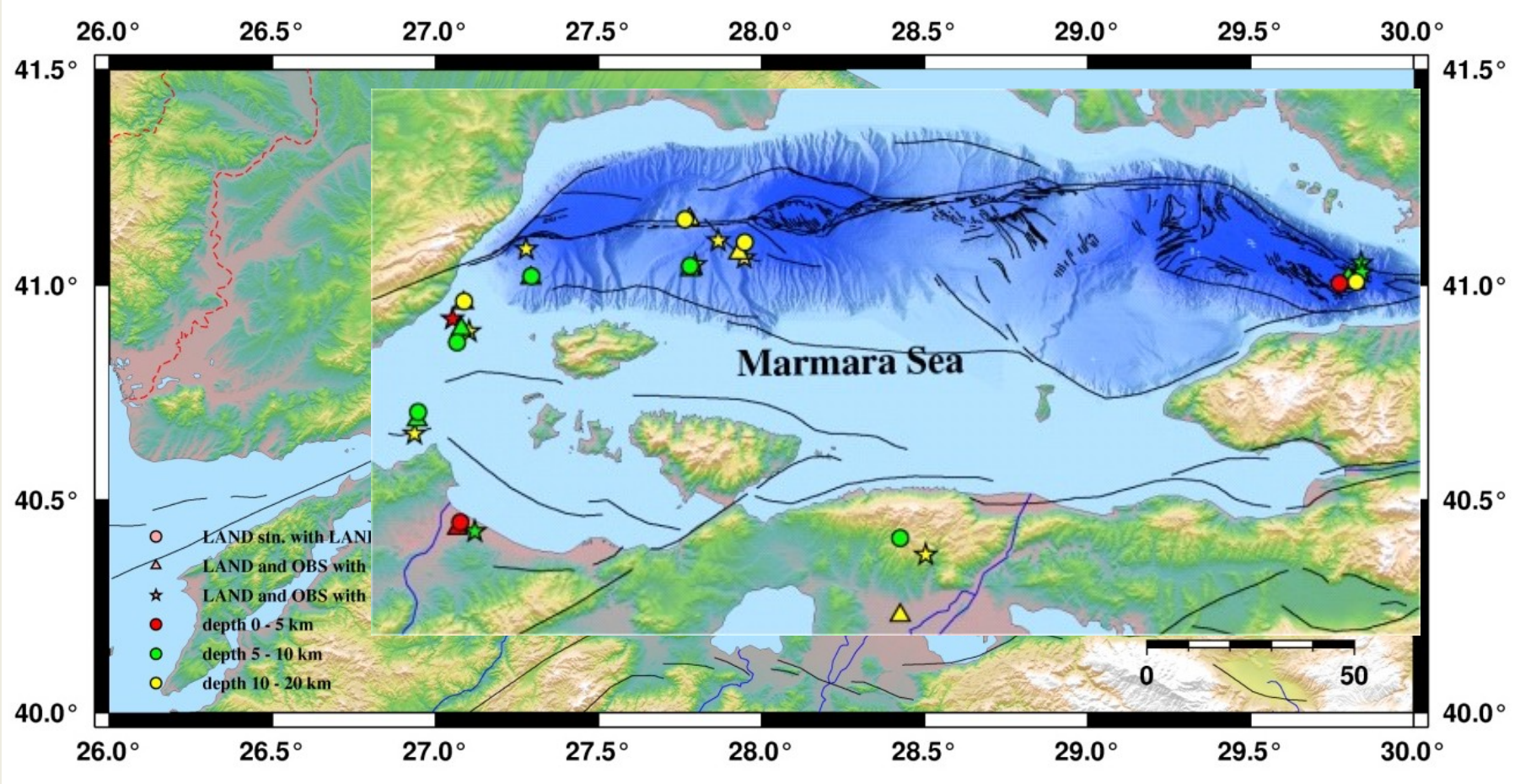
Color gives depth range of earthquakes



OBOL

O location done using land stations with land model (SEISAN)
Δ location done using Land and OBS stations with land model (SEISAN)
***** location done using Land and OBS stations with sea model (SEISAN)

Color gives depth range of earthquakes



Conclusions

- Installation of the five Sea Bottom Observatory systems in the Marmara Sea is one of the first project done in the inland sea.
- The SBO systems and addition of new 10 broadband stations to the land station network increased location capability of the KOERI seismic network in the Marmara Sea.
- Threshold level of the earthquake magnitude reduced from 2.5 to 1.0.
- 1-D velocity model is not enough to locate combined land and SBO data.
- Construction of a 3-D velocity model from existing geophysical studies and development of 3-D earthquake location program will increase location accuracy of the Marmara Sea earthquakes.

Conclusions

- Our knowledge about the crustal structure beneath the Marmara Sea is known up to depths of 10 kms. By analyzing regional and teleseismic earthquake recordings from SBO stations it can be possible to determine crustal structure beneath the sea of Marmara.

- Multiparameter geophysical measurements with the SBO systems will make a big contribution to the existing KOERI early earthquake and tsunami warning systems.

- Recordings of the small earthquakes which are not seen on the land stations can give valuable information for the expected Marmara earthquake.

Thank you