



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

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KOERI SEISMIC NETWORK

- ✓ Land Stations
 - Weak Motion Stations
 - Strong Motion Stations
- ✓ Sea Bottom Observatories
- DATA COMMUNICATION
- DATA PROCESSING
- SPECIFICATIONS OF THE KOERI SEA BOTTOM OBSERVATORIES
- SAMPLE APPLICATIONS FOR THE MARMARA SEA EARTHQUAKES
- CONCLUSIONS





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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)



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DATA PROCESSING





- 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)



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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 |
|---------|------|-----------|-----------|----------------------|--------------|-----------|---------|
| | Sea | 40.705638 | 29.149183 | 10000 | 31.12.2010 | 1260 | 156.7º |
| 080-1 | Land | 40.657299 | 29.191900 | 10000 | | | |
| | Sea | 40.878619 | 28.514247 | 10000 | 03.11.2010 | 810 | 23.8° |
| 060-2 | Land | 40.999814 | 28.507368 | 10000 | | | |
| | Sea | 40.884783 | 27.975100 | 12000 | 21.01.2011 | 1204 | 308.7º |
| 080-3 | Land | 40.965266 | 27.944733 | 12000 | | | |
| | Sea | 40.828184 | 27.535460 | 10000 | 22 12 2010 | 1144 | |
| 080-4 | Land | 40.862821 | 27.459275 | 10000 | 22.12.2010 | | 200.0* |
| | Sea | 40.631132 | 28.880385 | 0000 | 09.06.2010 | 368 | 100.00 |
| 080-5 | Land | 40.591945 | 28.907368 | 9000 | | | 192.Z° |







Location map of Sea-bottom observatories







Sample record: SBO1 (All sensors)





| HYD | 4 | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 2.326+04 |
|---------|---------|---|------|--|----------|---------------|------|-------------|--------|-------------|---------|------------------|
| delta | 0.1 | | | , lit | | | | | | | | |
| depmin | -23809 | | | | | | | | | | | |
| depmax | 19273 | | | 10 | | | | | | | | |
| b | 0 | | | 5 | | | | | | | | -1.99E+D |
| DPG1 | Z 🖌 | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 1.56E+D5 |
| delta | 0.1 | | | 0.55 | | | | | | | | |
| depmin | -95364 | | | 1.1.11 | | | | | | | | 1000 |
| depmax | 146984 | | | | | | | | | | | - 0 · |
| b | 0 | - | | h., | | | | | | | | -8.59E+D |
| ACC1 | BHE | | 60 | ón | 120 | 150 | 190 | 210 | 240 | 270 | 300 | 4.89E+D4 |
| delta | 0.01 | | 00 | 00 | 120 | | 100 | 210 | 240 | 210 | 500 | |
| depmin | -31806 | | | 100 | | | | | | | | |
| depmax | 57893 | 2 | | | | | | | | | | |
| b | 0 . | - | | 1 | | | | | | | | -4.08E+04 |
| ACC1 | BHN | | | | | | | | | | | Li manine |
| delta | 0.01 | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 1,230+00 |
| denmin | -60392 | | | 2 | | | | | | | | |
| depmax | 123989 | | | | | | | | | | | -0 |
| h | 0 | | | | | | | | | | | -S ISEAN |
| ACC4 | PU7 | | | · · · · · · | | · · · · · · · | | | | | | |
| ACCI | 0.04 | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 3.19E+04 |
| denmin | 59000 | | | - | | | | | | | | |
| deprint | 100990 | | | T | | | | | | | | |
| uepmax | 0 | | | 1 | | | | | | | | |
| D. | | | | | | | | | | | | -4.40E+04 |
| VEL1 | BHE | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 2.18E+D6 |
| delta | 0.01 | | | h., | | | | | | | | |
| depmin | -42482 | - | | | | | | | | | | -8 |
| depmax | 111021 | | | () | | | | | | | | 10 M P |
| a | U | 1 | | | | | | | | | | -2.18E+D6 |
| VEL1 | BHN | · | 60 | 98 | <u> </u> | 150 | 180 | 2 <u>10</u> | 240 | 270 | 300 | 101E+06 |
| delta | 0.01 | | | | | | | | | | | |
| depmin | -52406: | | | | | | | | | | | |
| depmax | 583885 | | | | | | | | | | | |
| b | 0 | 1 | | | | | | | | | | -5.36E+06 |
| VEL1 | BHZ | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 1.44E+05 |
| delta | 0.01 | | 2000 | 1000 | 020253 | | 2022 | | 123.00 | | 150,312 | |
| depmin | -11813: | | | a state of the local division of the local d | | | | | | | | |
| depmax | 143126 | | | T | | | | | | | | |
| b | 0 , | - | | [| | | | | | | | -1.17 E+D6 |
| | | | | | | | | | | | | |





Sample record: All SBO BBs with land stations





| VEL1 | BHE | - | 30 Mananana | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | 50 | 60 | 70 | 80 | |
|-------|-------------|---|--|---|--|--|--|--|--|
| delta | 0.01 | - | . Million . Million | | | | | 1 1991 - 8,003 (1 1992) (1992) | 0 012 0220 Address |
| detta | 0.01 | ÷ | 30 | v ⁴⁰ | 50 | 60 | 70 | 80 | |
| BUY | BHE | | 30 | 40 | 50 | 60 | 70 | 80 | |
| delta | 0.01 | - | and the second sec | | | | | | |
| BUY | BHZ | - | | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | 60 | | 80 | |
| delta | 0.01 BHE | ÷ | | 10 Jac 19 19 19 19 19 19 19 19 19 19 19 19 19 | 20 | | 70 | 00 | |
| delta | 0.01 | - | | month the second | mannan | www. | ************************************** | ······································ | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ |
| VEL5 | BHZ | | 30 | And Charles and a second second | ulutineties 50 marchine | <u> 60 </u> | 70 | 80 | |
| delta | 0.01 | - | Line of the | a Randon and a shirt of the second | | of south the same south the | | | 1910) 305 30 |
| detta | BHE 0.02 | ÷ | <u>30</u> | | | analylegytesty water for an all and a second | 70, | 80 | |
| ARMT | BHZ | | 30 J | | | 60 | 70 | 80 | |
| delta | 0.02 | - | | | and he want to be a set of the se | ** | | | |
| ISK | BHE | - | 30 | 40 | 50 States of the second | 60 | 70 | 80 | |
| delta | 0.02 | | | | , , , , , , , , , , , , , , , , , , , | | | | |
| delta | 0.02 | ÷ | 30 | | &;;;;; ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;; | 60 ****** | 70 | 80 | |
| VEL2 | BHE | | 30 | 40 | | the function of the state of th | M Then berthe . | AL. 1 | Marshare more Marshare |
| delta | 0.01 | - | | | and the second sec | with with the stand of the stand of the stand | and radiation dates when the same | AN AND AN AN AN AN AN AN AN AN AN | |
| VEL2 | BHZ | 1 | | | | What while was a serie and a serie of the series of the se | May and a second and a second and the second and th | /www.water | and all and a survey and a state of the second |
| CTKS | BHE | Ť | 20 | 40 | | الماسية المارية الم | 70 | 00 | |
| delta | 0.02 | - | | 40 Arritorit | a wind we an in the last of the second | | tindel \$1988,999∰tingtala fila fila tina tina tina ang ina ang Ina ang ina ang | | ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,, |
| CTKS | BHZ | | | 40 | and marine Science and the fill | and she at a label of the label of the second s | and the second second second second second | | |
| delta | 0.02 | - | | | All a line of the second s | an a | | | 1990-1990-1990-1990-1990-1990-1990-1990 |
| VEL3 | BHE 0.01 | ÷ | 30 | 40 | 50 | | wellerwanter englanger and | mound | - |
| VEL3 | BHZ | | 31 | | Selection and a second selection | | المحمد والمتعالية والمتعادية والمتعالية | | has marine to be the |
| delta | 0.01 | + | | | A CONTRACTOR OF A CONT | and the second se | WINDER AND A CONTRACTOR OF A CONTRACT | ₩₩₩₩₩₽₽₽₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩₩ | and the second second second |
| VEL4 | BHE | | 30 | 40 | 50 | | | Marghan marghan marghan marghan | MAMMANMANA |
| delta | 0.01 | | 500 | local de la companya | | | | 8.18048.945.9468.9468.9468.94 | |
| delta | 0.01 | ÷ | | 40 | | ๛๚๛๛๛๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚๚ | hand the second of the second s | hter here here here here here here here | Any my may many water |
| RKY | BHE | - | 30 | 40 | 50 | 60. | | | |
| delta | 0.02 | - | | | | | | numera an an an an an Alind An an Alind An | |
| RKY | BHZ | | 30 | 40 | 50 | | had was no was the second and the second | un mun march when m harm | human |
| delta | 0.02 | - | 201031 82 33 30 | | | . We are discontine to a contract of the | | A Man Later to A later of the l | e weiver |



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)







ΚΑΥΜΑΚ





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Horizontal Comp.





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

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

OBO4

OBO3



OBO5









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





Horizontal Comp.

Vertical Comp.

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

KAYMAK



Coordination Workshop (Integrating Seafloor and land-based seismographic observations) Lisbon May 2011





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

OBO1





120S VELOCITY 31 (blue)

10⁻¹

OBO2



-180

-200

10-2

10-1

Acquired: 08.02.2011 01:01:15 UTC

100

Frequency (Hz)

10⁵

NLNM (Blue)

10

10

NLNM (Blue)

101





Vertical Comp.

Horizontal Comp.



Specrum of (2011.02.08 01:56:38; M=2.7) earthquake

recorded at SBO stations (cont.)

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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 |
|----------------------|-----------------------|------------|----------|--------|
| | Land stations | Land model | SEISAN | Ο |
| NOBOL | OBS stations | Land model | SEISAN | Δ |
| | OBS stations | Land model | NLLOC | * |
| | Land stations | Land model | SEISAN | Ο |
| NOBOLL | Land and OBS stations | Land model | SEISAN | Δ |
| | Land and OBS stations | Land model | NLLOC | * |
| | Land stations | Land model | SEISAN | Ο |
| NOBOLS | Land and OBS stations | Sea model | SEISAN | Δ |
| | Land and OBS stations | Sea model | NLLOC | * |
| | Land stations | Land model | SEISAN | Ο |
| NOBOS | OBS stations | Sea model | SEISAN | Δ |
| | OBS stations | Sea model | NLLOC | * |
| | Land stations | Land model | SEISAN | Ο |
| ОВО | OBS stations | Land model | SEISAN | Δ |
| | OBS stations | Sea model | SEISAN | * |
| | Land stations | Land model | SEISAN | 0 |
| OBOL | Land and OBS stations | Land model | SEISAN | Δ |
| | Land and OBS stations | Sea model | SEISAN | * |



Earth Models used in sample applications





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)
- ▲ 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)
- ▲ location done using Land and OBS stations with sea model (SEISAN)
- Iocation done using Land and OBS stations with sea model (NLLOC)
 Color gives depth range of earthquakes





NOBOS

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

Color gives depth range of earthquakes



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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)
- ▲ 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.









- 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

