P5.2-260

International cooperation in seismic monitoring across the Arabian Peninsula

A. Chiang[1], I. El-Hussain[2], Y. Al-Rawahi[2], H. Al-Shukri[3], H. Mahdi[3], K. Yousef[4], A. Hosny[4], A. Al-Amri[5], E. Bozdağ[6]

[1]Lawrence Livermore National Laboratory, [2]Sultan Qaboos University, [3]University of Arkansas at Little Rock, 4Saudi Geological Survey, [5]King Saud University, [6]Colorado School of Mines

Lawrence Livermore National Laboratory

INTRODUCTION AND MAIN RESULTS

This presentation highlights current research projects with our partners in Iraq, Oman and Saudi Arabia to improve seismic monitoring across the Arabian Peninsula Our projects cover a wide variety of topics including seismic source studies, seismic hazard assessments, seismic detections and adjoint waveform tomography.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. The views expressed here do not necessarily reflect the opinion of the United States Government, the United States Department of Energy, or LLNL

SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

International cooperation in seismic monitoring across the Arabian Peninsula

A. Chiang, I. El-Hussain, Y. Al-Rawahi, H. Al-Shukri, H. Mahdi, K. Yousef, A. Hosny, A. Al-Amri, E. Bozdağ

P5.2-260

Introduction

Increasing urban development combined with damage from recent earthquakes highlight the need for resilient infrastructure and better understanding of seismic hazard.

During the past several decades, the expansion of national seismic networks and data collection in the Middle East have improved seismic monitoring and contributed to emergency preparedness and response.

Lawrence Livermore National Laboratory (LLNL), through the US Department of Energy's Seismic Cooperation Program (SCP), conducts joint research and supports high-quality data collection in collaboration with international partners in the Middle East.

This presentation highlights current research projects with our partners in Iraq, Oman and Saudi Arabia, including:

- Regional data analysis
- Building sustainable seismic networks
- Monitoring of local seismicity
- Subsurface velocity model development
- Seismic hazard studies

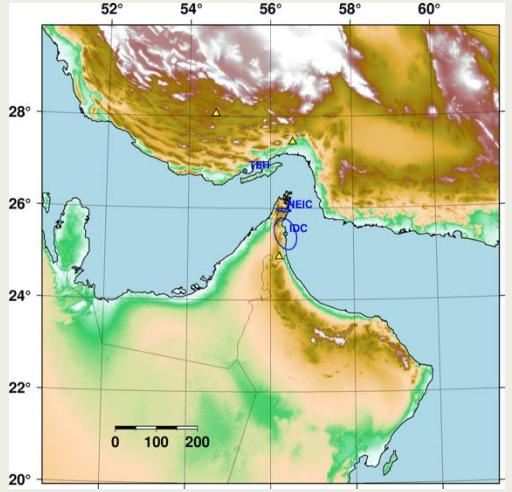
Regional Data Analysis

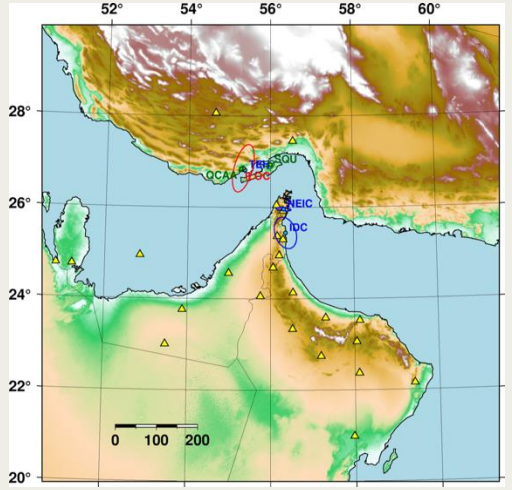
In collaboration with the Earthquake Monitoring Center at Sultan Qaboos University and the International Science and Technology Center, we conducted a regional data analysis workshop on location improvement using iLoc in Muscat, Oman, April 21 to 23, 2024.

Drawing on insights from previous Regional Seismic Travel Time (RSTT) workshops, we incorporated interactive Jupyter notebook wrappers to further enhance the training experience for participants.

Experts from Iraq, Saudi Arabia, Oman, Qatar, Kuwait, UAE, Egypt and Morocco participated in the workshop and contributed seismic data from their regional networks.

Using the contributed picks from workshop participants, we demonstrated the importance in locating low- and moderate-magnitude earthquakes in the region.





This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

International cooperation in seismic monitoring across the Arabian Peninsula

A. Chiang, I. El-Hussain, Y. Al-Rawahi, H. Al-Shukri, H. Mahdi, K. Yousef, A. Hosny, A. Al-Amri, E. Bozdağ

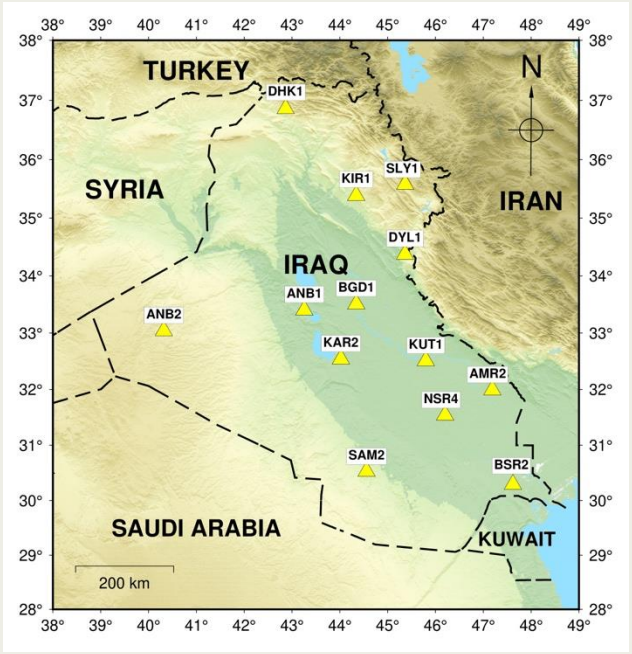
P5.2-260

Seismic Network Development in Iraq

For over two decades, SCP has been working with the University of Arkansas, Little Rock and Iraqi agencies and universities to improve and modernize seismic monitoring in the country:

- Installation and operation of broadband and strong motion seismic stations
- Updating seismic provisions of national building codes
- Collaboration and joint research with local seismologists to build in-country network operation and data analysis capacity

The Mesopotamian Seismic Network (MPSN) currently operates 13 broadband seismic stations and 7 strong motion stations. Real-time data are archived at the EarthScope Data Management Center. Photos to the right are taken from the installation of Karbala (KAR2).



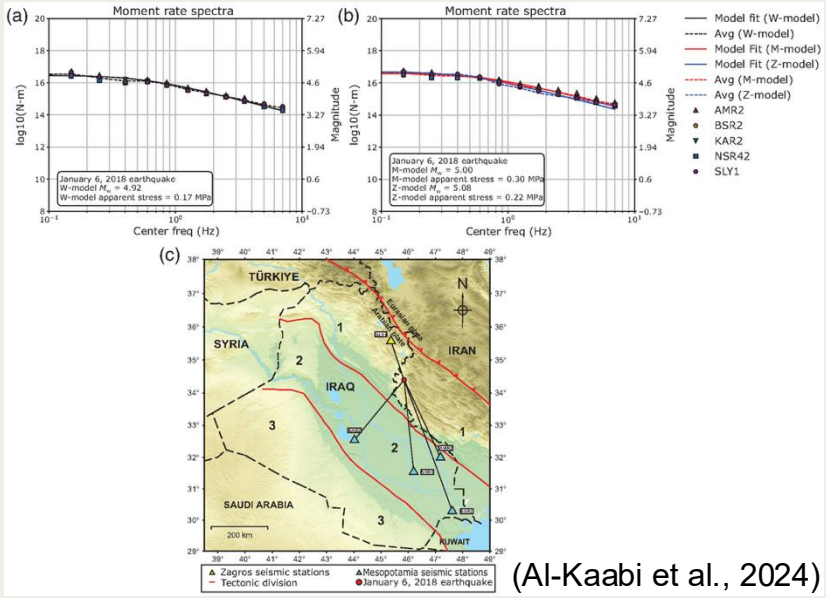
Research Activities

Coda moment magnitude (Mw) estimation (Al-Kaabi et al., 2024)

- Develop a reliable estimate of moment magnitude for Iraq using in-country data and coda calibration technique to estimate coda envelope-derived measurements.
- Investigated the reliability of using a 1D coda envelope model by comparing three different calibrations.
- For selected events, computed stable apparent stress that were used as ground truth references to constrain the high frequency site terms.

Probabilistic Seismic Hazard Assessments (Abdulnaby et al., 2025)

- A comprehensive update of earthquake seismic hazard assessment for Iraq
- More than 37,000 earthquakes between 1900 and 2021 were used and more than 2,800 direct calculations of Mw
- Data from 30 strong motion stations were used to validate Ground Motion Models



(Al-Kaabi et al., 2024)

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

International cooperation in seismic monitoring across the Arabian Peninsula

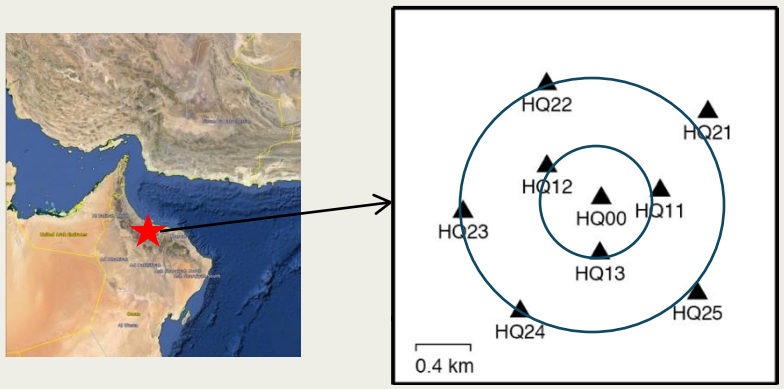
A. Chiang, I. El-Hussain, Y. Al-Rawahi, H. Al-Shukri, H. Mahdi, K. Yousef, A. Hosny, A. Al-Amri, E. Bozdağ

P5.2-260

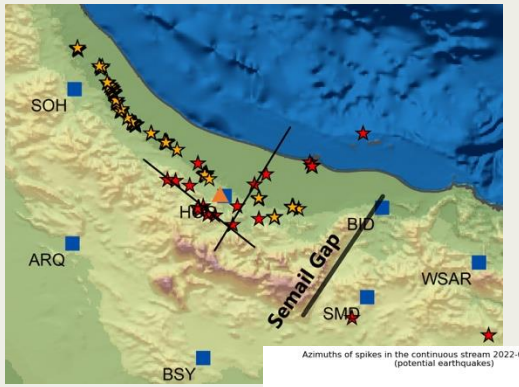
Seismic Arrays

HQAR
- In collaboration with the Earthquake Monitoring Center of Sultan Qaboos University, a nine-element array was installed in 2015.
- Array aperture is about 3.5 kilometers with minimum element spacing about 500 meters.
- Beamforming of array data resulted in detections of local seismicity not detected by the permeant network.

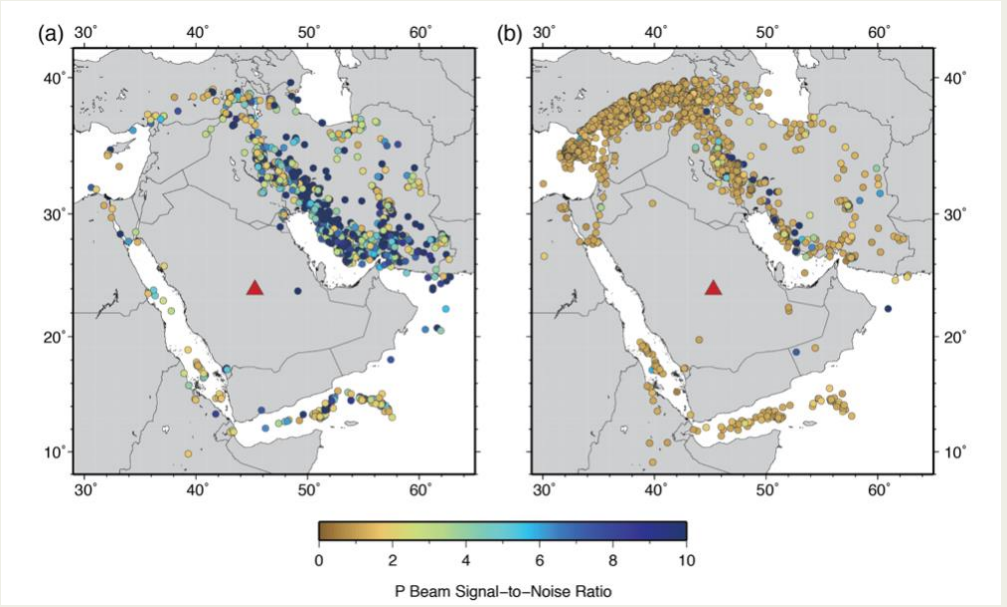
QWAR
- In collaboration with King Saud University the nine-element array was installed in 2012.
- Strong, local, and persistent noise sources in the region as well as high attenuation in the collision zones surrounding the Arabian Peninsula likely play a role in the array's event detection capabilities.
- Majority of events with magnitudes over 3.0 are detected, over 82% for events with magnitudes over 4.0
- The dominant ambient seismic noise sources travel with an apparent velocity of Lg waves.
- The strongest sources are from the northern Gulf and the southern Red Sea

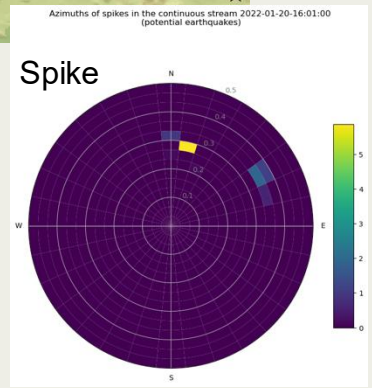


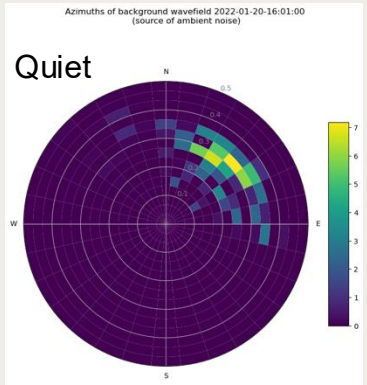
2016 detections (Yasir Al-Rawahi)



Pyle et al. (2020)







2022 noise analysis (Eric Matzel)

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

International cooperation in seismic monitoring across the Arabian Peninsula

A. Chiang, I. El-Hussain, Y. Al-Rawahi, H. Al-Shukri, H. Mahdi, K. Yousef, A. Hosny, A. Al-Amri, E. Bozdağ

P5.2-260

Middle East Tomography Project

A tri-lateral project with the Saudi Geological Survey and Colorado School of Mines.

Multiple efforts in imaging the structure of the region:

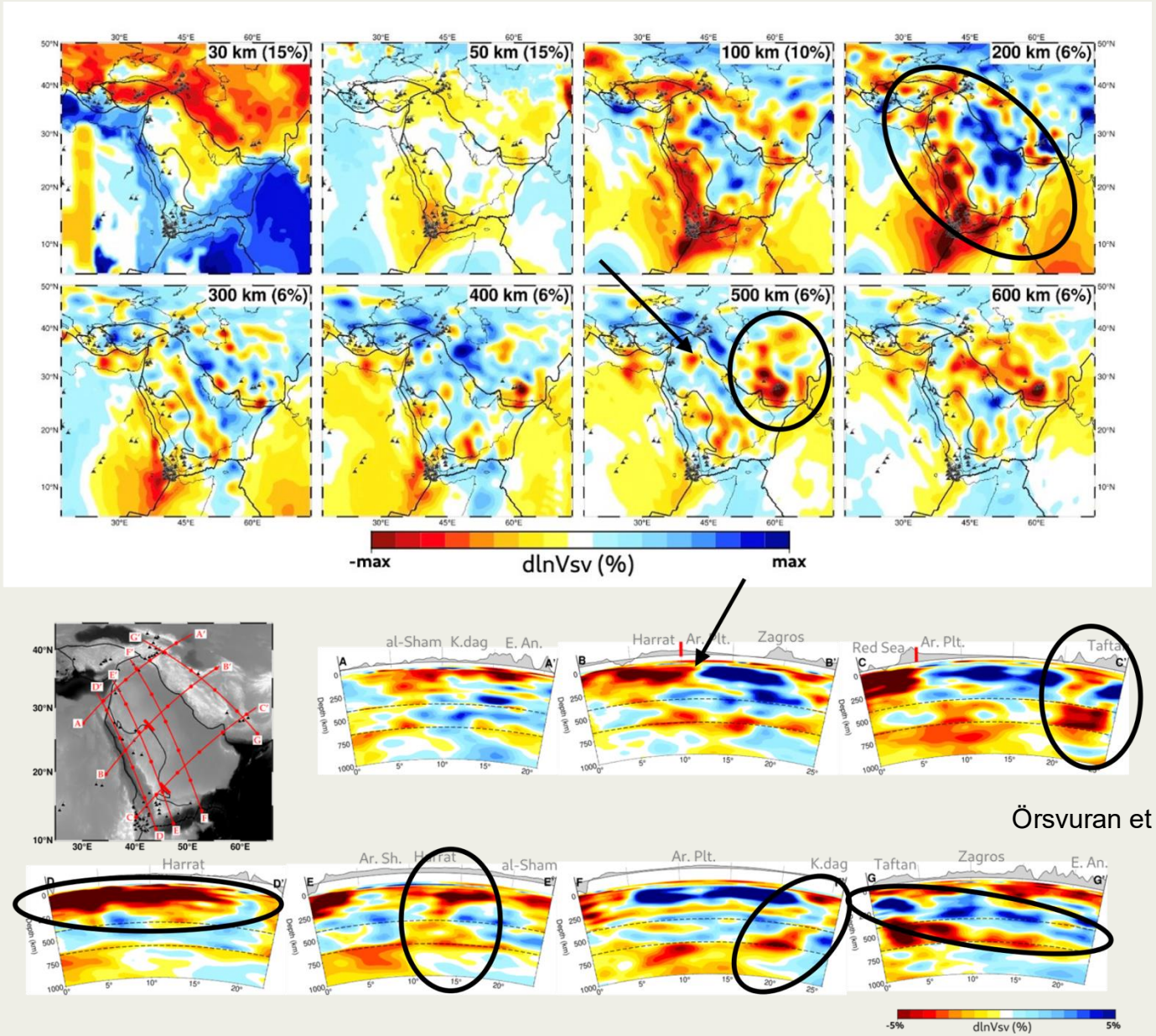
- Bozdağ, Desilva, Nolet, Örsvuran, Gök, Tarabulsi, Hosni, Yousef, Mousa, 2025. P-Wave Arrival-Time Tomography of the Middle East using ISC-EHB and Waveform Data, Seismica (supported by AFRL, LLNL, partial support from NSF)
- Örsvuran, Bozdağ, Peter, Chiang, Gök, Tarabulsi, Hosny, Yousef, Mousa. Adjoint Tomography of the Middle East (supported by LLNL).
- Örsvuran, Bozdağ, Chiang, Gök Tarabulsi, Hosny, Yousef, Mousa. Azimuthally Anisotropic Adjoint Tomography of the Middle East (supported by LLNL).

The transversely isotropic model:

- Subduction along the Hellenic Arc and Bitlis-Zagros Suture Zone.
- Low wavespeeds from the Afar plume and evidence for volcanism related to the Jordan plume.
- Has been shown to improve the uncertainties in the source inversions (Rodríguez-Cardozo et al., 2024).

We will explore the use of azimuthally anisotropic model in source studies, since azimuthal anisotropy can also provide benefit for reducing uncertainties.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.



Örsvuran et al. (in prep)

SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

International cooperation in seismic monitoring across the Arabian Peninsula

A. Chiang, I. El-Hussain, Y. Al-Rawahi, H. Al-Shukri, H. Mahdi, K. Yousef, A. Hosny, A. Al-Amri, E. Bozdağ

P5.2-260

Summary

- Current projects cover a wide variety of topics including seismic source and structural properties, as well as seismic hazard assessments and building code modernization.
- Partner countries are highly encouraged to share data among regional networks and with the scientific community.
- Collaboration generates opportunities to improve regional earth models and refine event analyis.
- We partner with national and international organizations to provide regional data analysis workshops (both in-person and virtual).
- Please check out our E-poster by El-Hussain et al. on the relocation of Oman seismicity using iLoc and Bayesloc (P1.2-274).

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.