EDIS

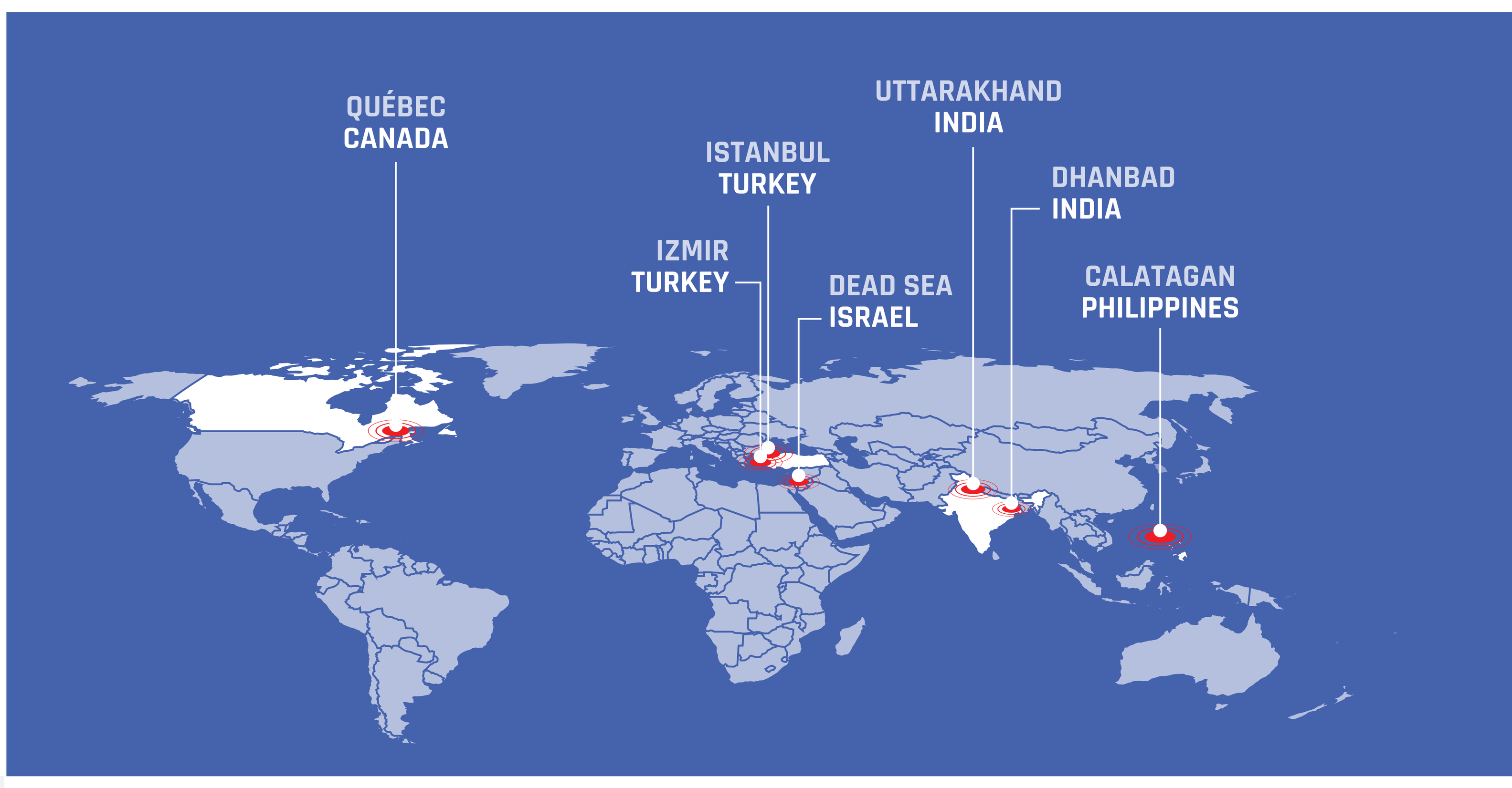
SCIENCE

01 REAL-TIME TESTED

Our pilot early warning systems have been installed in Canada, Turkey, Israel and India, and another system is being deployed in the Philippines. We have detected and located in real time dozens of events using only one or two stations.

NOTABLE DETECTIONS:

* M5.3 in Turkey – epicenter 100km offshore using only two stations
* M4.7 in Istanbul – offshore using a single station in a noisy environment
* M3.4 in Canada – located in under 3 seconds of origin time using a single station



$$\begin{pmatrix} x^n_{12} & x^e_{12} \\ x^n_{23} & x^e_{23} \\ x^n_{13} & x^e_{13} \end{pmatrix} \begin{pmatrix} S_e \\ S_n \end{pmatrix} = \begin{pmatrix} \Delta t_{12} \\ \Delta t_{23} \\ \Delta t_{13} \end{pmatrix}, \qquad (1)$$

$$\mathrm{SLO} = (S_e^2 + S_n^2)^{1/2} \qquad (2a)$$

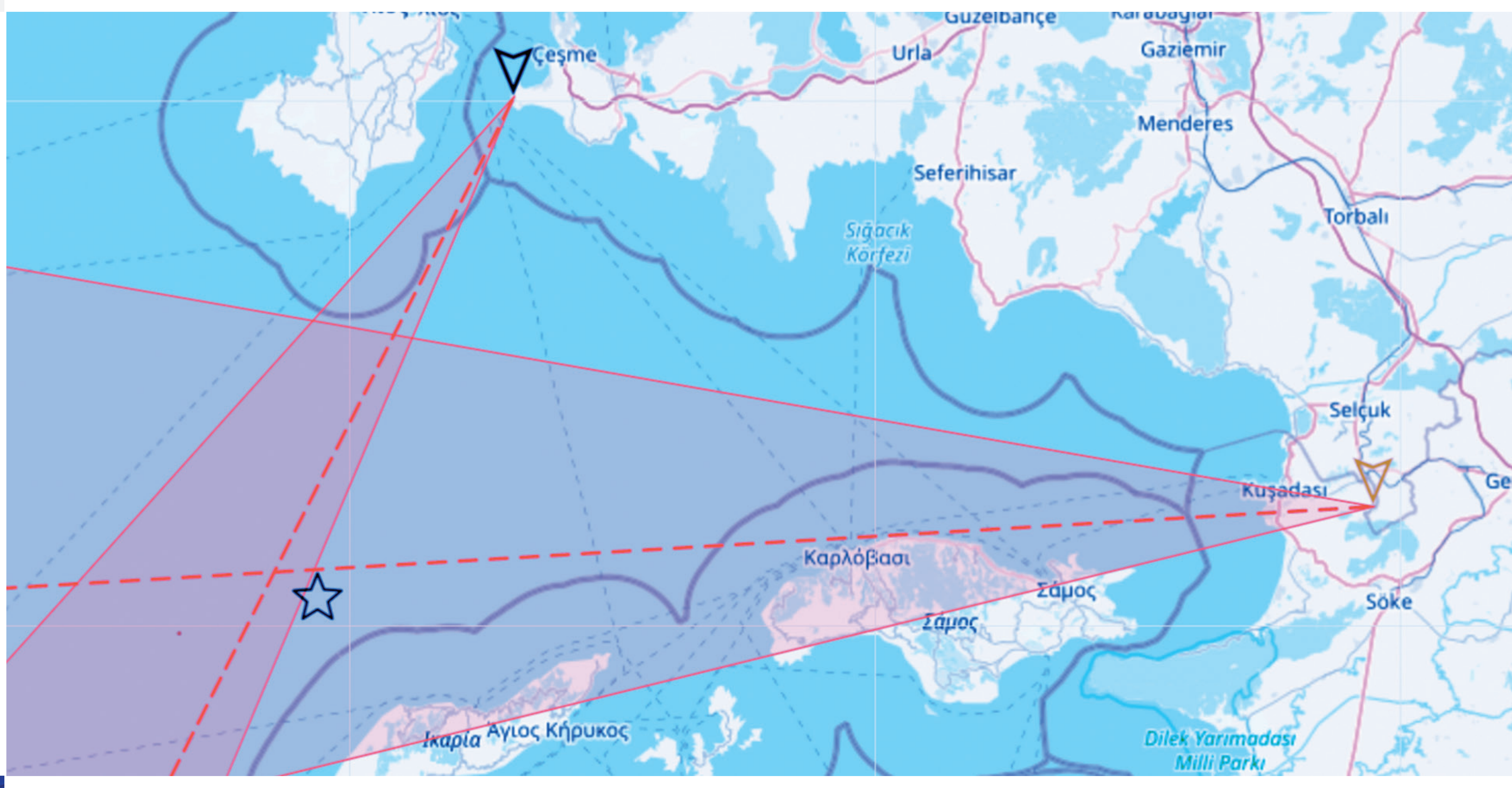
$$\mathrm{BAZ} = \mathrm{atan2}(S_e, S_n). \qquad (2b)$$

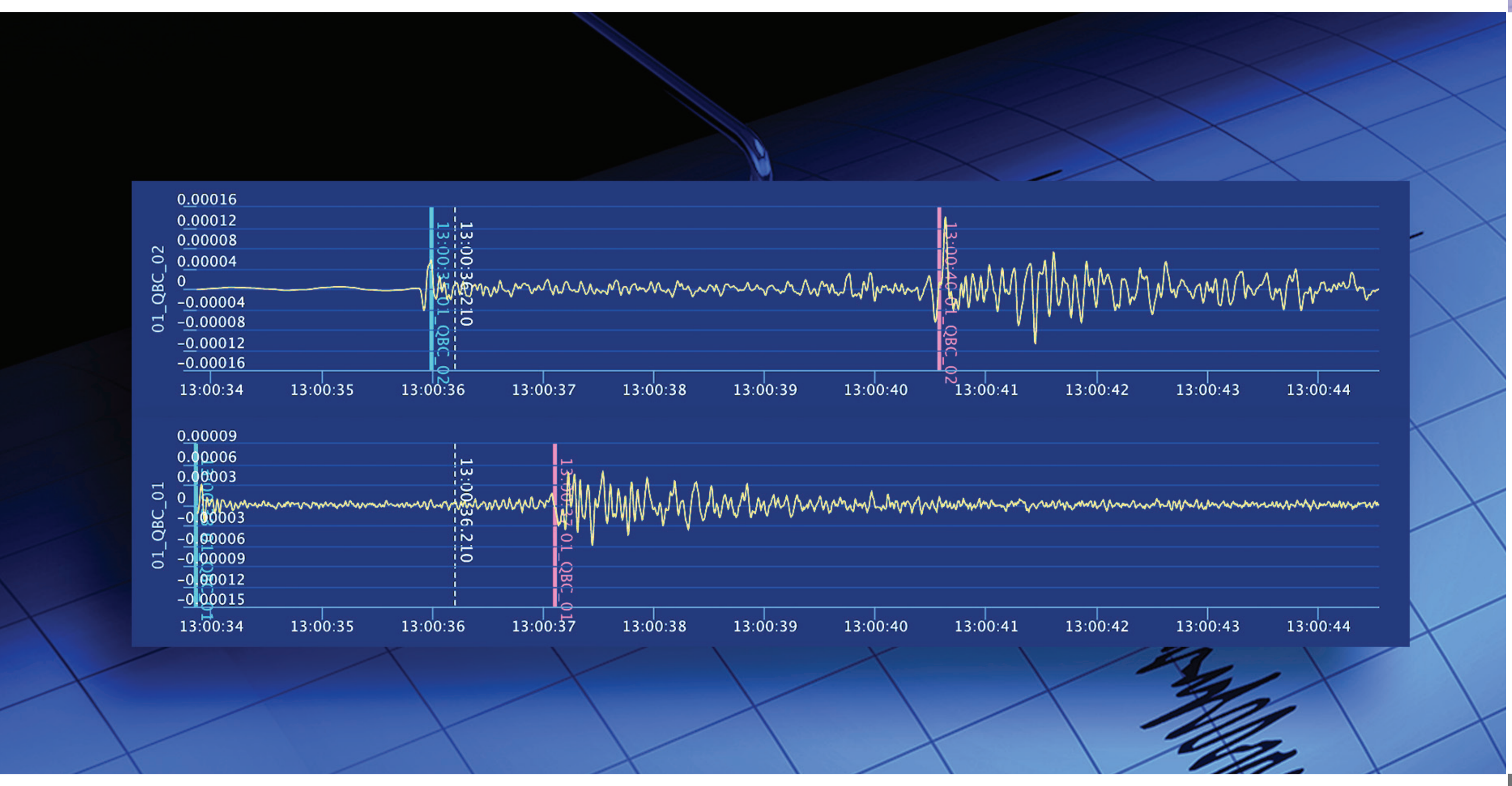
02 ARRAY SEISMOLOGY

The core challenge of EEW systems is to generate reliable predictions based on only a few seconds of waveform data. Seismic arrays are systems of linked sensors spread over hundreds of meters that can extract more information from incoming waveforms compared to a single-sensor station. The additional information provided by array-based measurements, such as slowness and back azimuth, can lead to better ground motion predictions as well as reduce the number of stations needed for a reliable location. We use seismic arrays alongside traditional single-sensor stations to provide an optimal solution.

03 OFF-NETWORK LOCATION

In many places around the world, large magnitude earthquakes can happen outside the seismic network, such as offshore or in neighboring countries. Thanks to the back azimuths calculated by the arrays in under 300ms from the P-wave arrivals, our system can reliably locate events outside the seismic network using only two stations..



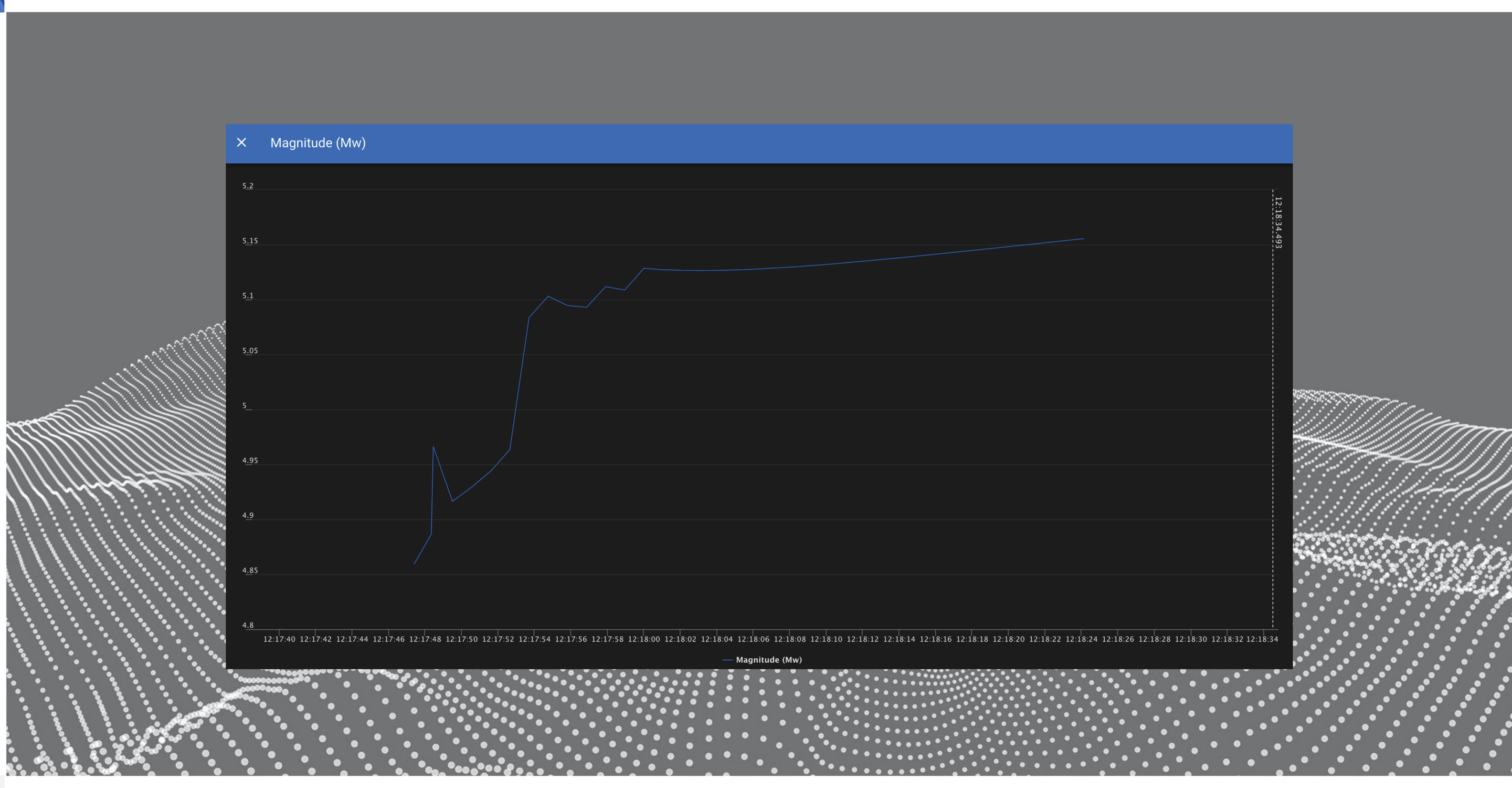


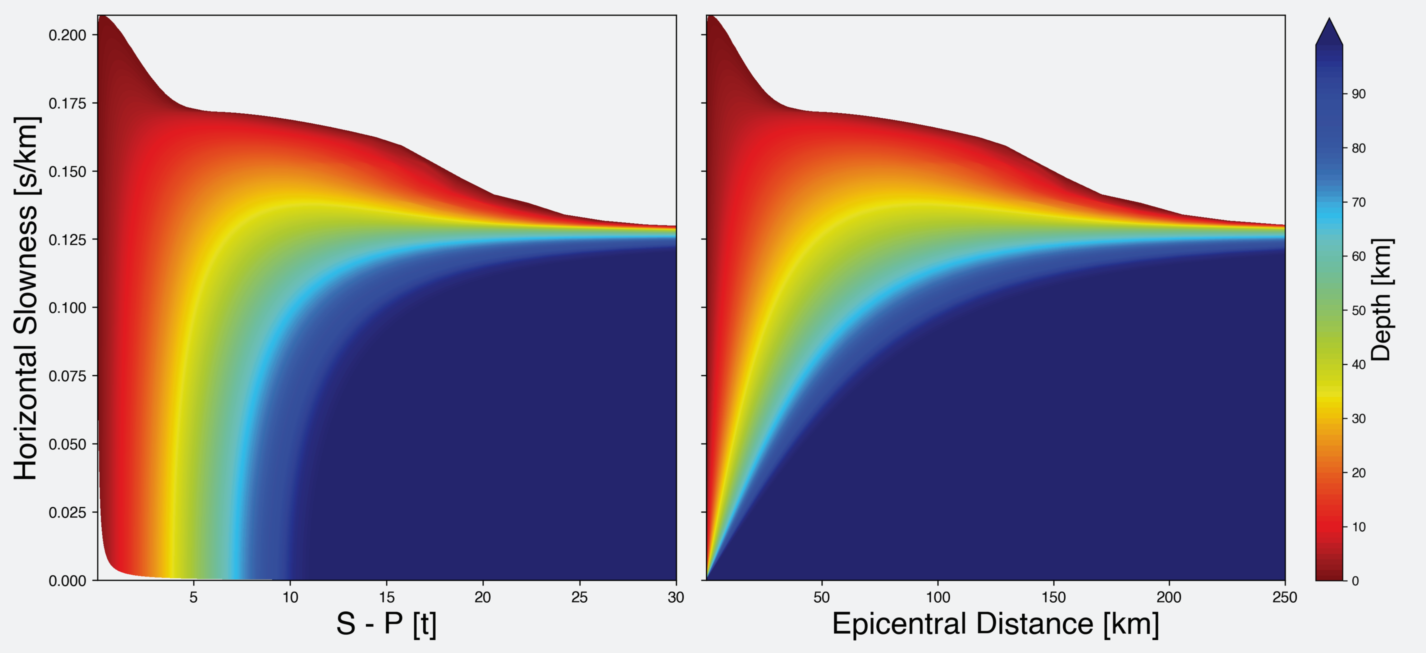
04 S-WAVE DETECTION AND UTILIZATION

The core challenge of EEW systems is to generate reliable predictions based on only a few seconds of waveform data. Seismic arrays are systems of linked sensors spread over hundreds of meters that can extract more information from incoming waveforms compared to a single-sensor station. The additional information provided by array-based measurements, such as slowness and back azimuth, can lead to better ground motion predictions as well as reduce the number of stations needed for a reliable location. We use seismic arrays alongside traditional single-sensor stations to provide an optimal solution.

05 EVOLUTIONARY MAGNITUDE ESTIMATES

We use an evolutionary algorithm that continuously updates the magnitude estimates with each incoming data sample and is not restricted to a fixed time interval. The algorithm is based on a relationship between the signal's RMS, the hypocentral distance and the magnitude, derived using the omega-squared model (Brune, 1970) and Prsaval's theorem. This evolutionary approach allows the algorithm to correctly characterize large earthquakes which have a long rerupture process.





06 REAL-TIME DEPTH

The horizontal seismic slowness measured during the P-wave arrival can be used to backward raytrace along the ray path to estimate the event depth. This can be done in the distance domain using the epicentral distance calculated from crossing two P-wave back azimuths, or in the time domain if one P-wave pick or one S-wave pick is available, depending on which is available first. To avoid real-time raytracing, we pre-calculate the results for the entire possible range of inputs, allowing us to determine depth in real time with zero computational cost.

ROOTED IN ACADEMIA

Our earthquake early warning system is based on long-term, ongoing collaboration with Tel Aviv University and Prof. Alon Ziv's research group along with over a decade of research. We collaborate with leading seismological institutes around the world, including Natural Resources Canada, Indian Institute of Technology Roorkee, and the Geological Survey of Israel, which has integrated parts of our research into their national EEW system.

POWERED BY SeismicAI

KEY PUBLICATIONS:

* Eisermann, A.S., A. Ziv, and G.H. Wust-Bloch, 2018. Array-based earthquake location for regional earthquake early warning: Case studies from the Dead Sea Transform, Bull. Seism. Soc. Am.
* Lior, I., and A. Ziv, 2018. The relation between ground motion, earthquake source parameters and attenuation: Implications for source parameter inversion and ground motion prediction equations, J. Geophys. Res.
* Eisermann, A.S., A. Ziv, and G.H. Wust-Bloch, 2015. Real-time back azimuth for earthquake early warning, Bull. Seismol. Soc. Am.
* Netanel, M., Eisermann, A.S. and Ziv, A., 2021. Off-Network Earthquake Location by Earthquake Early Warning Systems: Methodology and Validation.Bull. Seismol. Soc. Am.