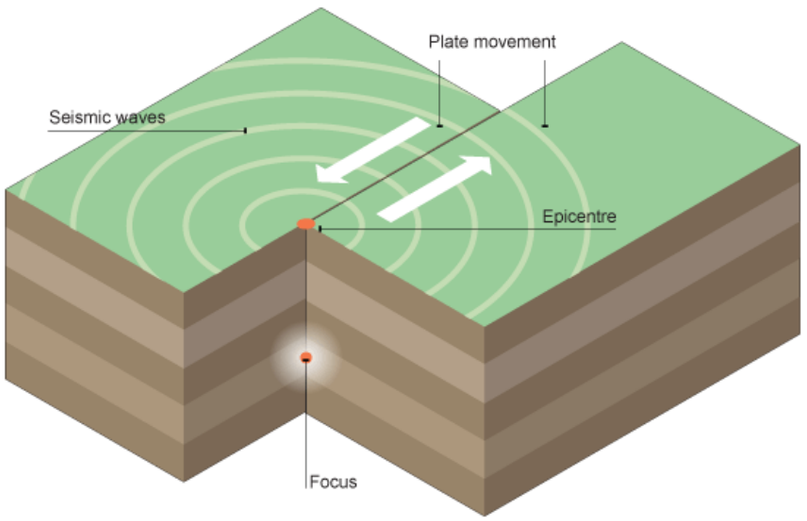
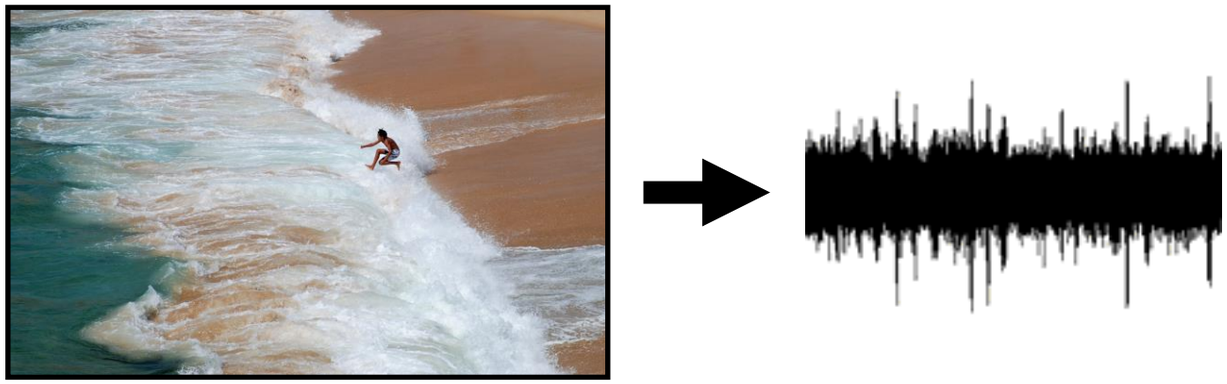
Two recent seismological applications implemented on the EGI



bbc.co.uk



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in collaboration with:
Nikolaï M. Shapiro, David Weissenbach
and Horst Schwichtenberg

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INSTITUT DE PHYSIQUE
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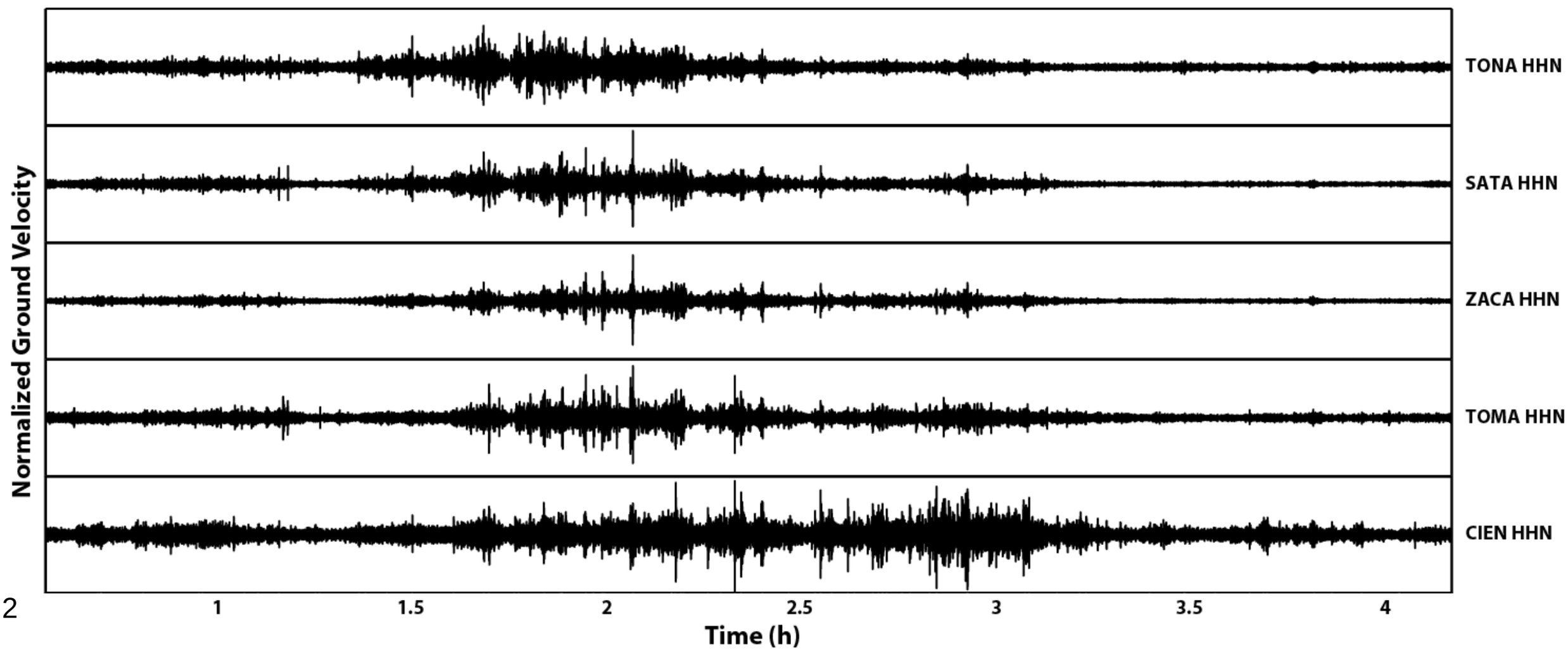
Automatic seismic event detection

- Not all seismic events are “loud” like large earthquakes
  - Signal-to-noise ratios too small for standard detection (i.e. STA over LTA[1])
- Specialized detection algorithms necessary
- No *a priori* temporal information ▶ **continuous application**

[1] = short-term average over long-term average

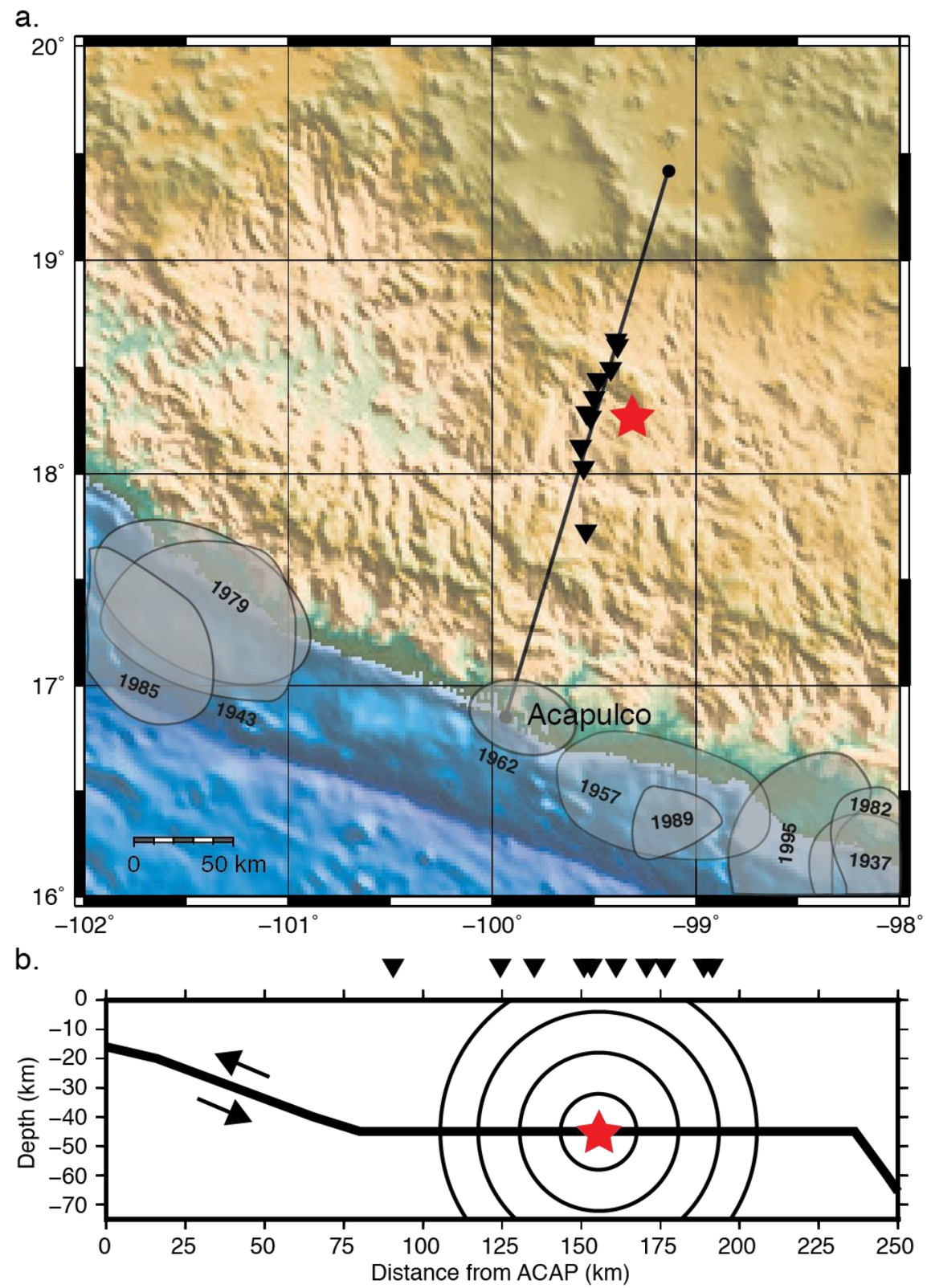


Beamformed network response 1/3

Method:

1. **Generate seismic wave travel times for a given source**
2. Align data with first arrival
3. Stack aligned energy (velocity squared) ▸ beamformed network response

Network response peaks indicate seismic energy originating the theoretical source

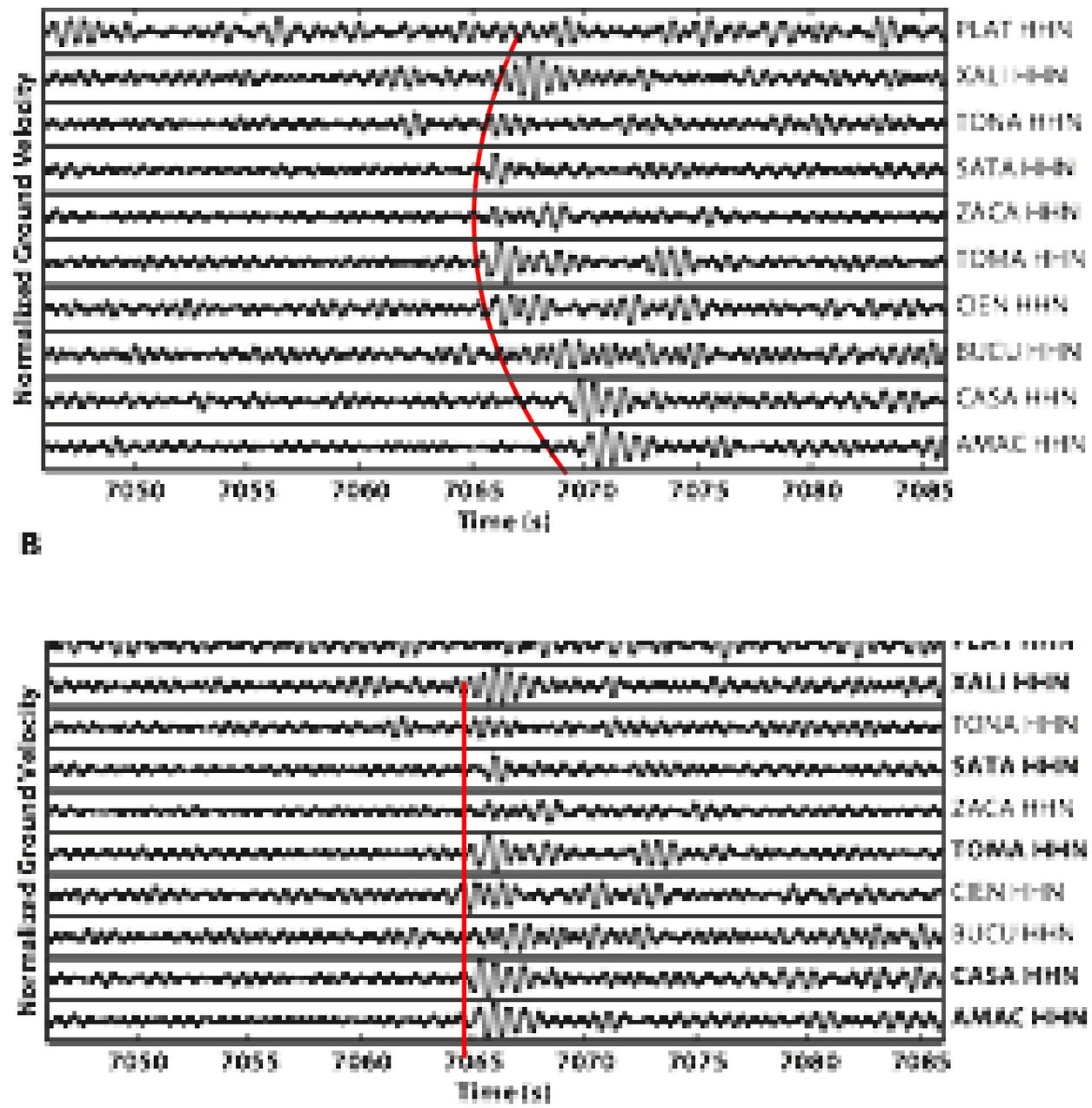


Beamformed network response 2/3

Method:

1. Generate seismic wave travel times for a given source
2. **Align data with first arrival**
3. Stack aligned energy (velocity squared) ▸ beamformed network response

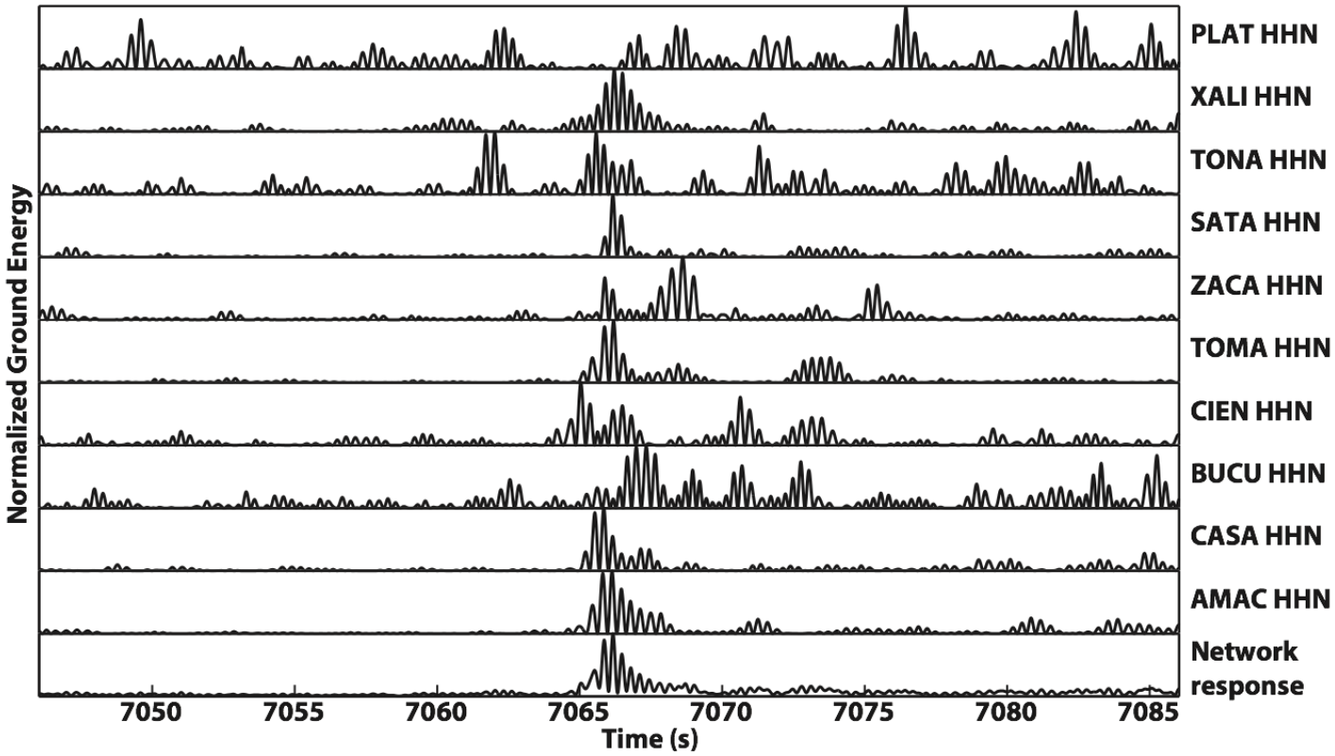
Network response peaks indicate seismic energy originating the theoretical source



Beamformed network response 3/3

Method:

1. Generate seismic wave travel times for a given source
2. Align data with first arrival
3. **Stack aligned energy (velocity squared) ▸ beamformed network response**

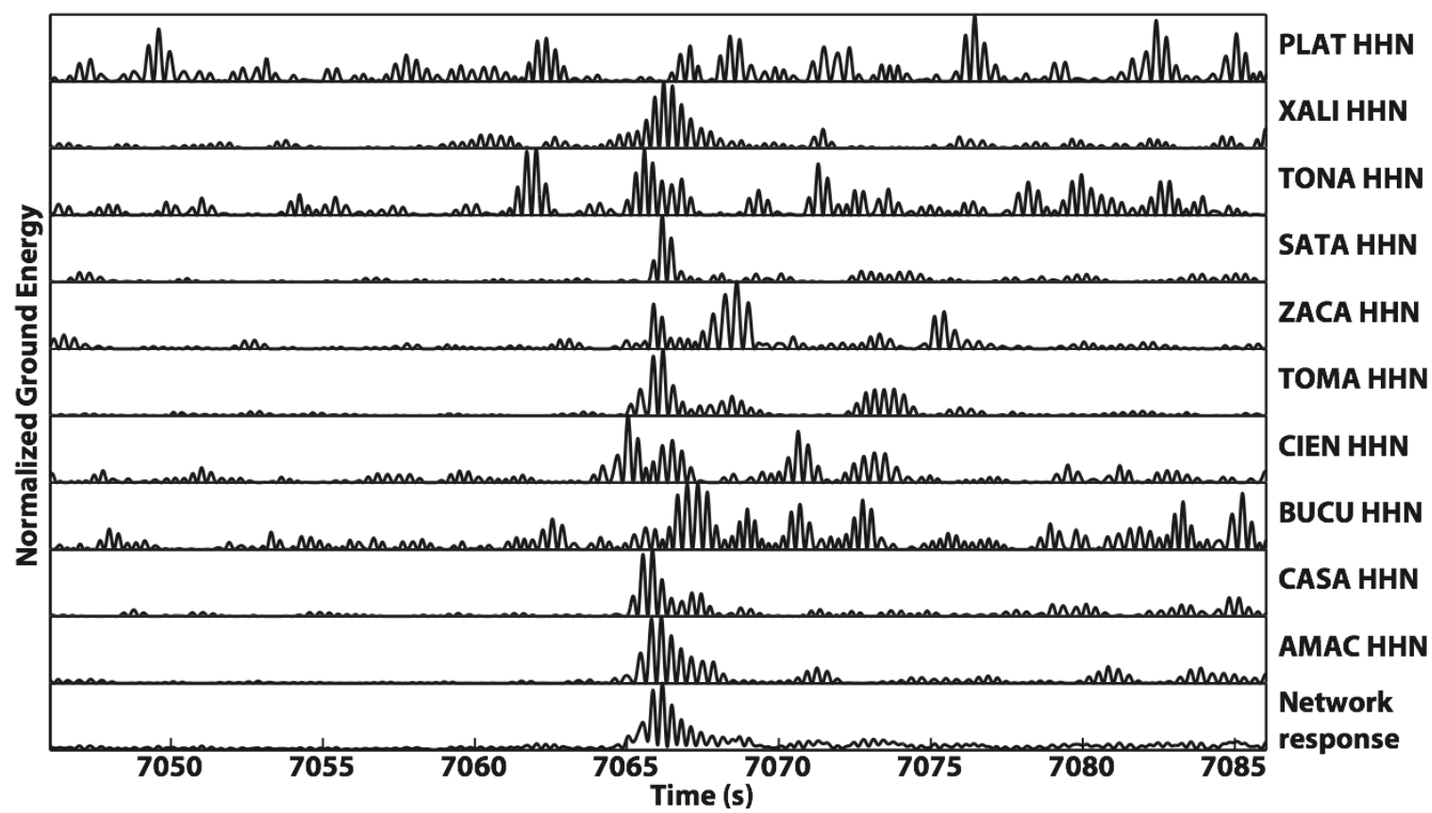


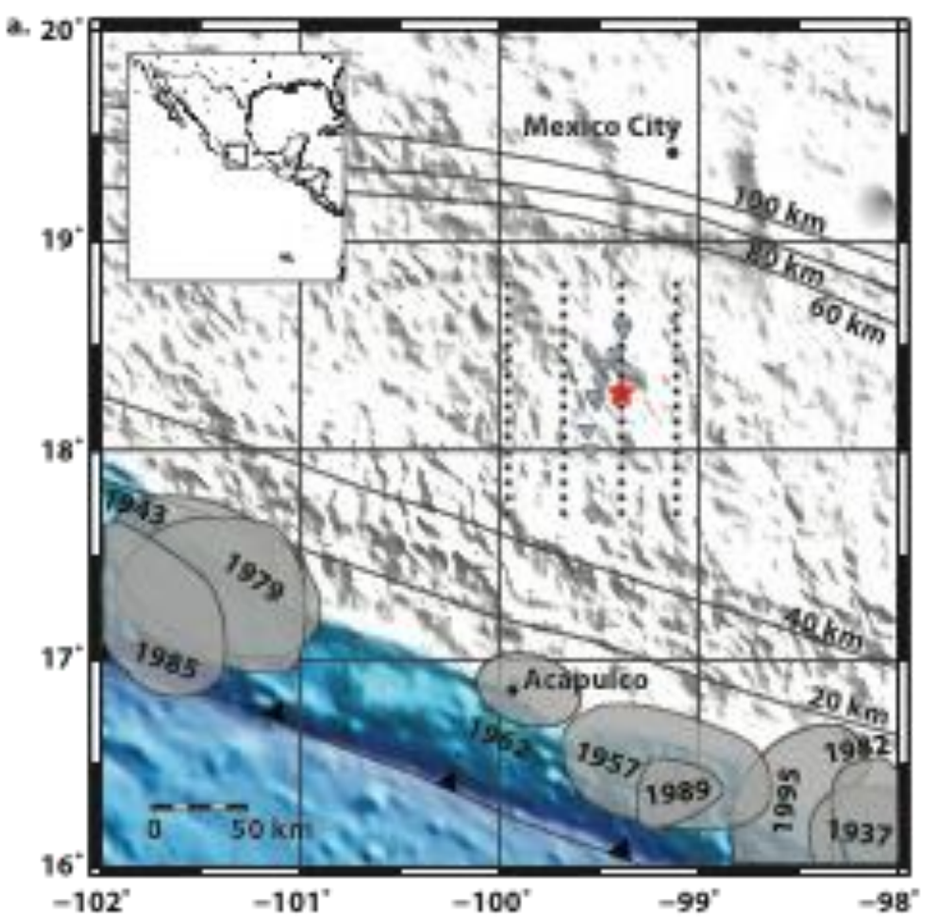
Network response peaks indicate seismic energy originating the theoretical source

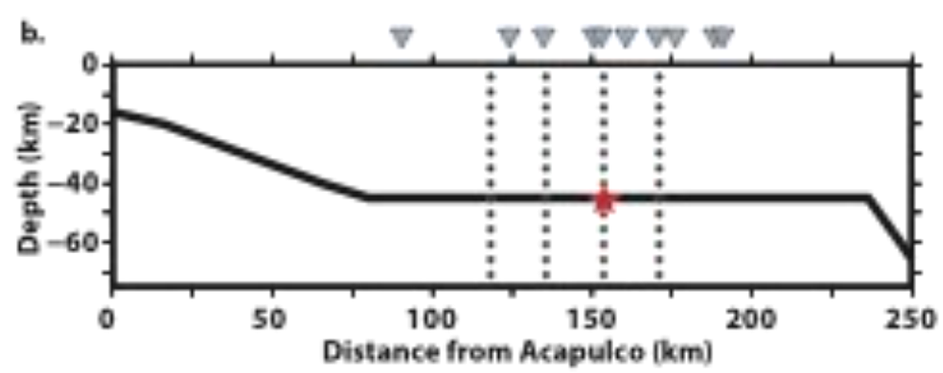
$$NR(\tau, \phi, \lambda, z) = \sum_i \frac{s_i(\tau, \phi, \lambda, z)^2}{\mathrm{RMS}\left(s_i(\tau, \phi, \lambda, z)^2\right)}$$

3-D grid search

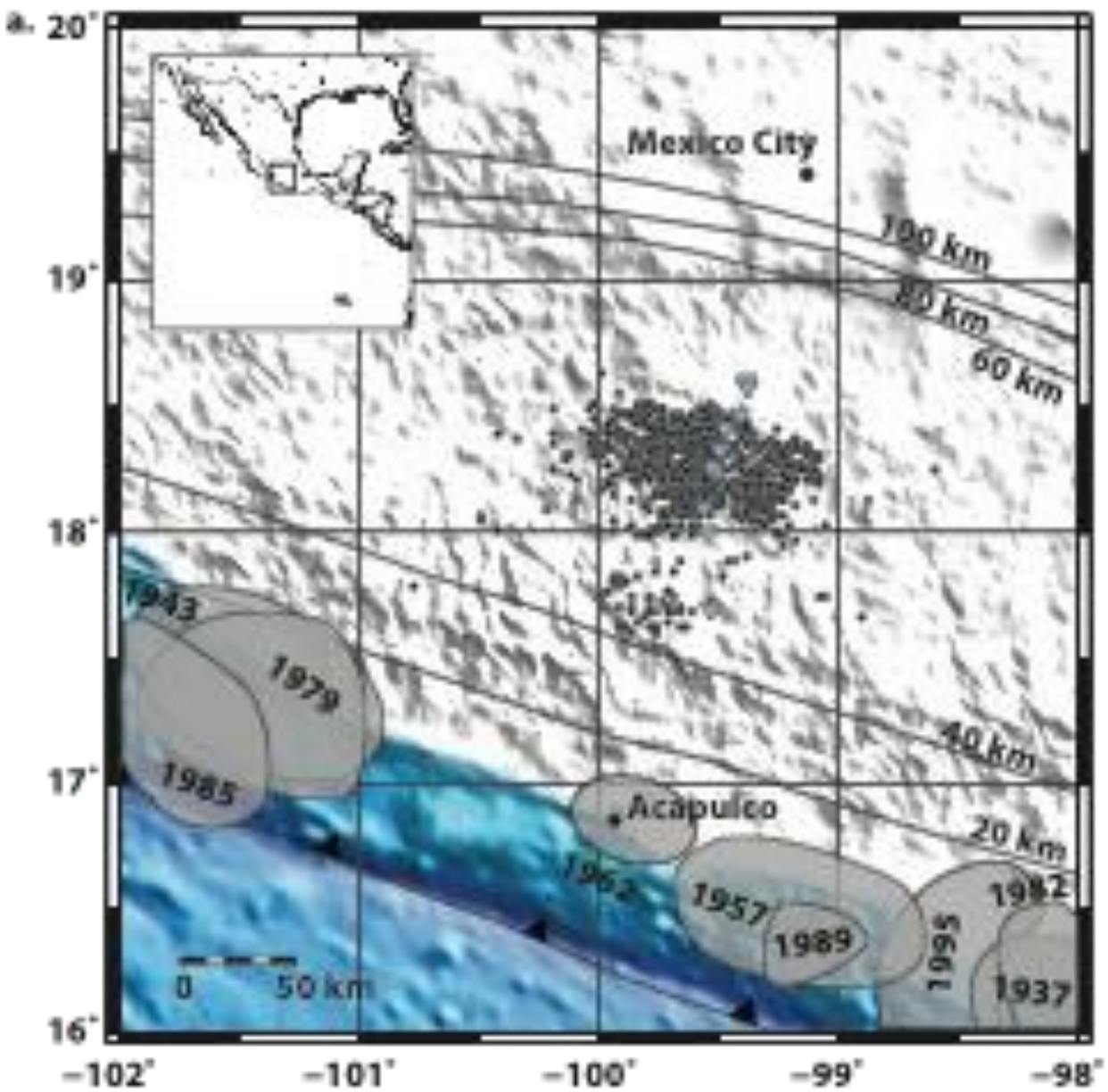
- Search for events within a 3-D grid of potential sources (100 x 100 x 75 = 750,000 potential sources)
- Each source completely independent ▸ ideal for EGI implementation



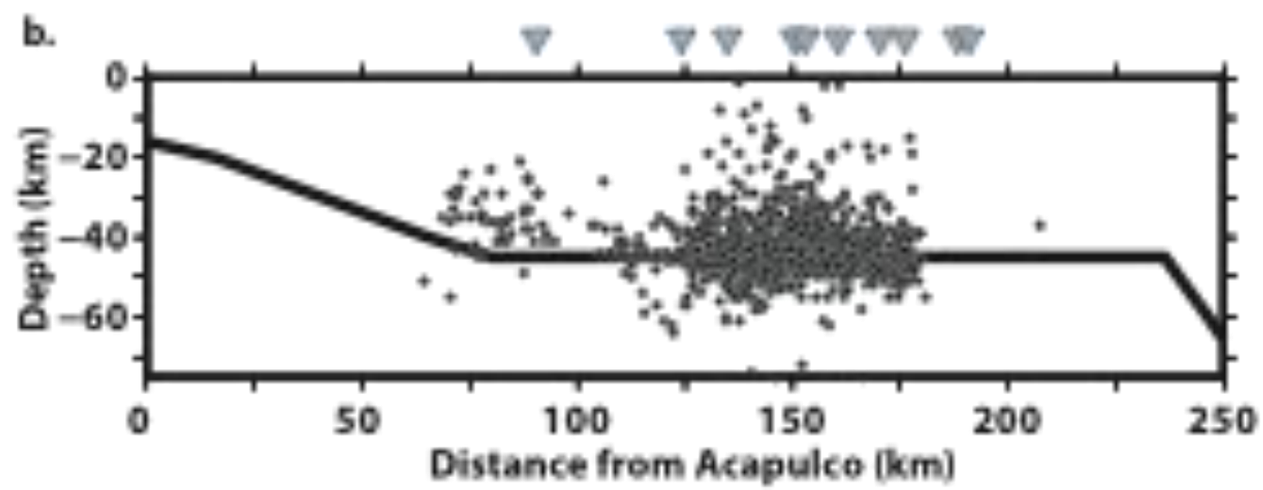




Resulting event catalog



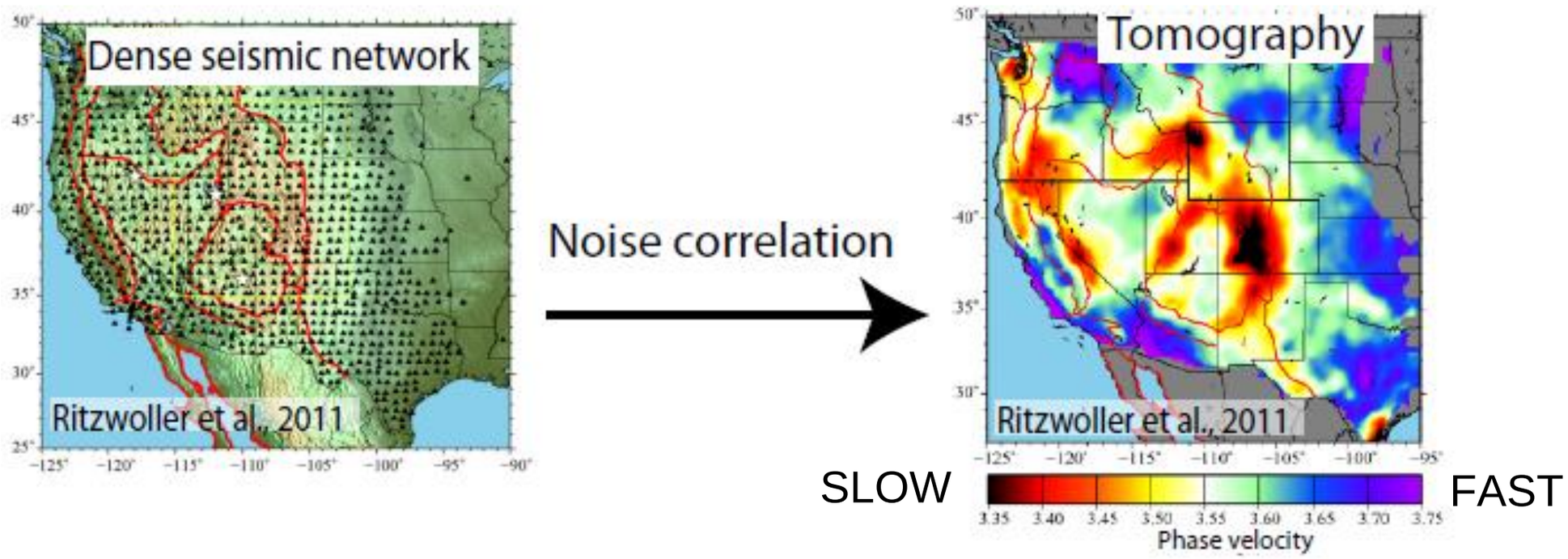
- 1120 events detected and located
- Previously undetected through visual inspection!



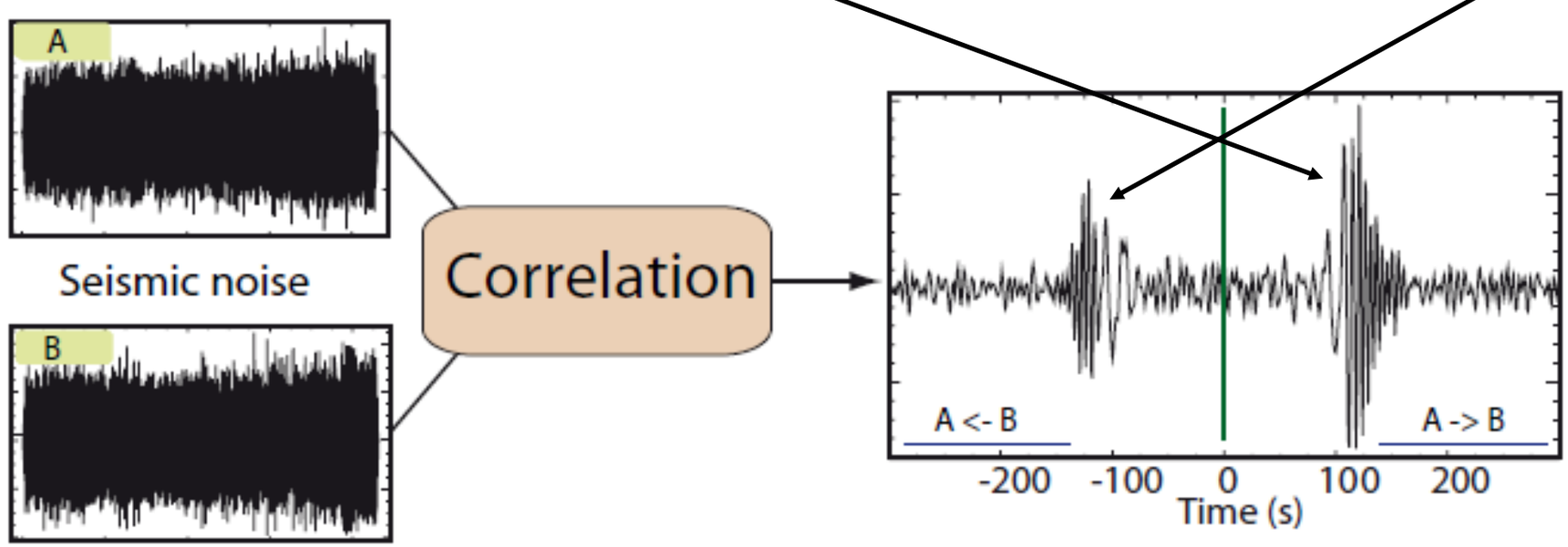
- Estimate on 1 CPU: 15 months
- Runtime on 30 CPUs: 25 days

High computational cost offset by parallel implementation ideal for EGI

Motivations

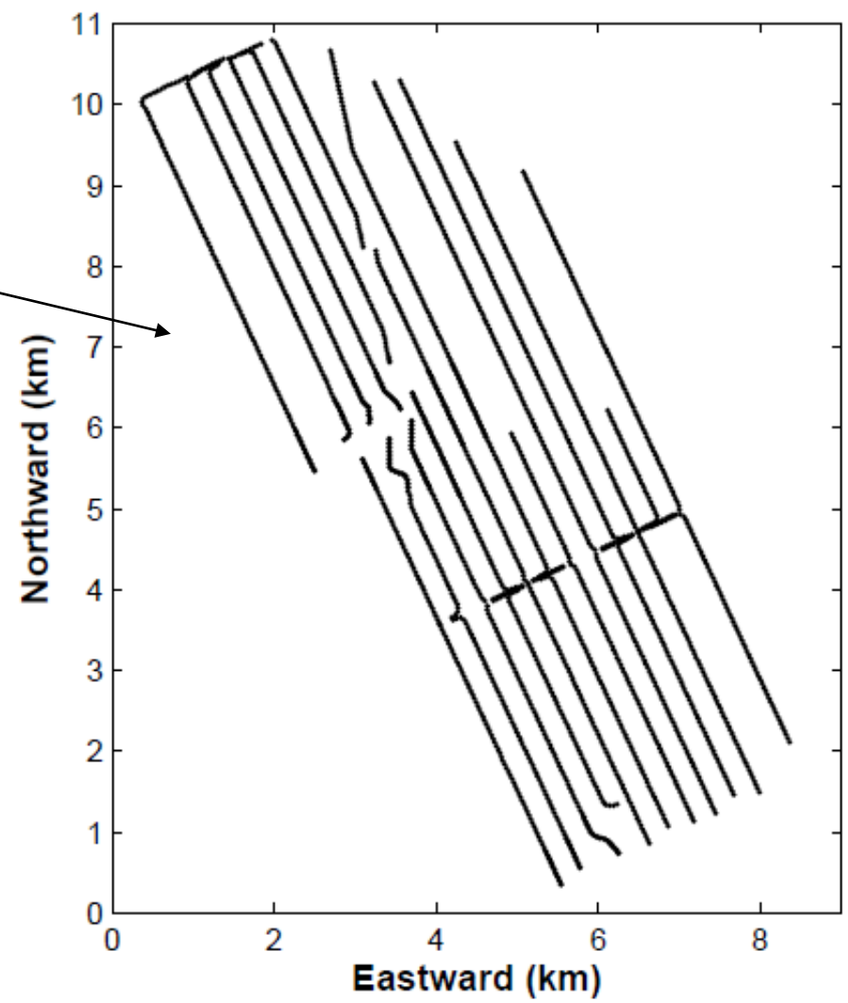


The correlation of seismic noise recorded at station A and B creates two waves as if station A was a seismic source emitting a wave recorded by station B and vice versa



These waves are used to compute images of the Earth crust called tomographies

- Usually seismometers record the ground motion with 3 components in 3 directions: East (E), North (N) and Vertical (Z)
- Therefore, for two different seismometers one can compute 9 different correlations: component E from station A with component E from station B, component E from station A with component Z from station B, etc.
- Additionally, from a set of N stations one can make N(N-1)/2 unique pairs of stations
- So with a network of N 3-components seismometers, it is possible to compute **<u>9 x N(N-1)/2 correlations!</u>**



The Valhall network with 2320 3-C seismometers on the seafloor above an oil reservoir

The data

- 6.5 hours of continuous data recorded at 250 Hz

  = 167 Gb of data to correlate
- **24,210,360 correlations**
- 4 min to compute 9 correlations from a pair of station
- 25.5 year if computed on 1 core !!!
  - parallelization needed
- **Computation done on the Grid with ~300 simultaneous tasks**

3 months of computation

→

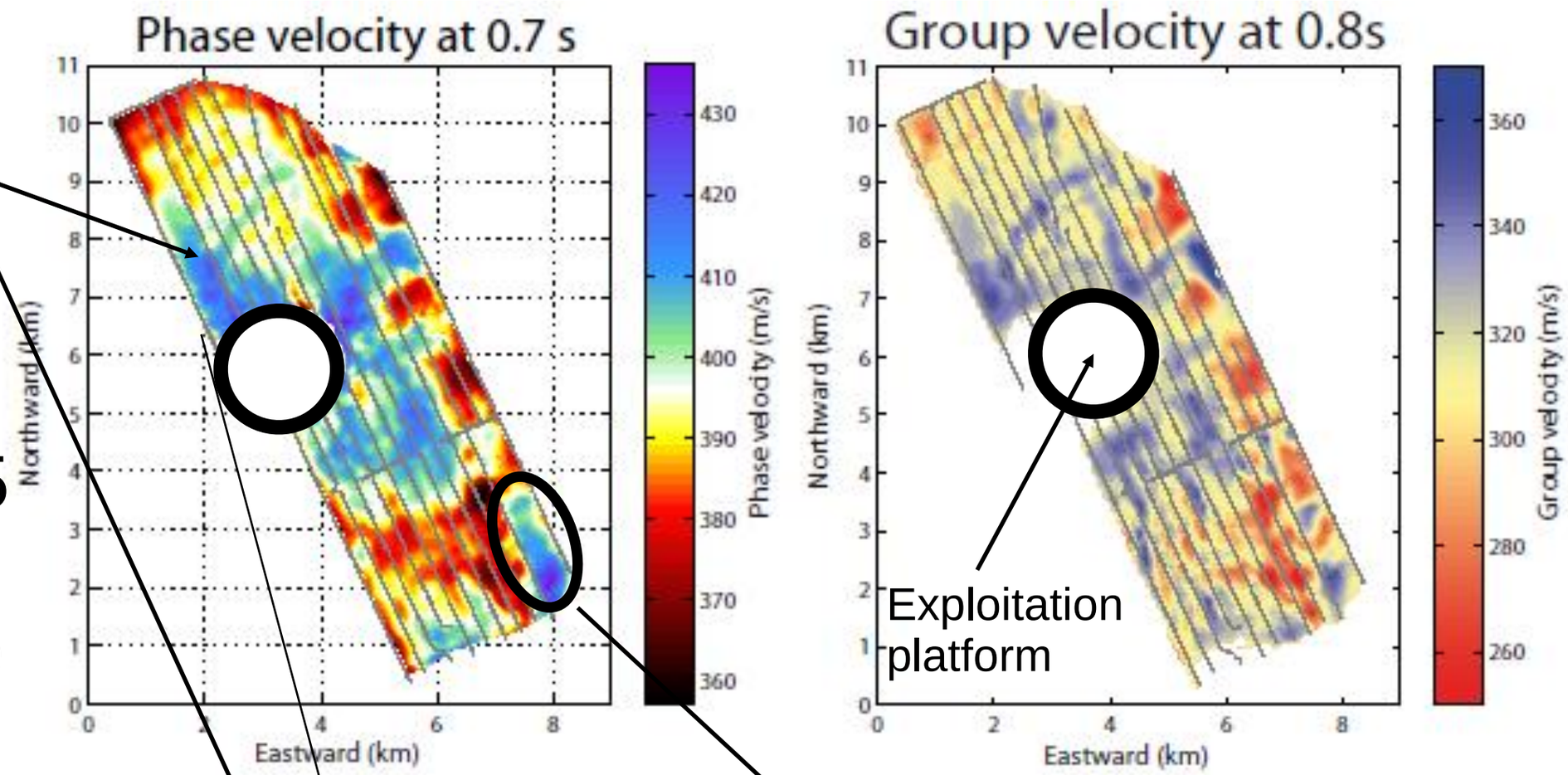
Results from 2 different methods of tomography

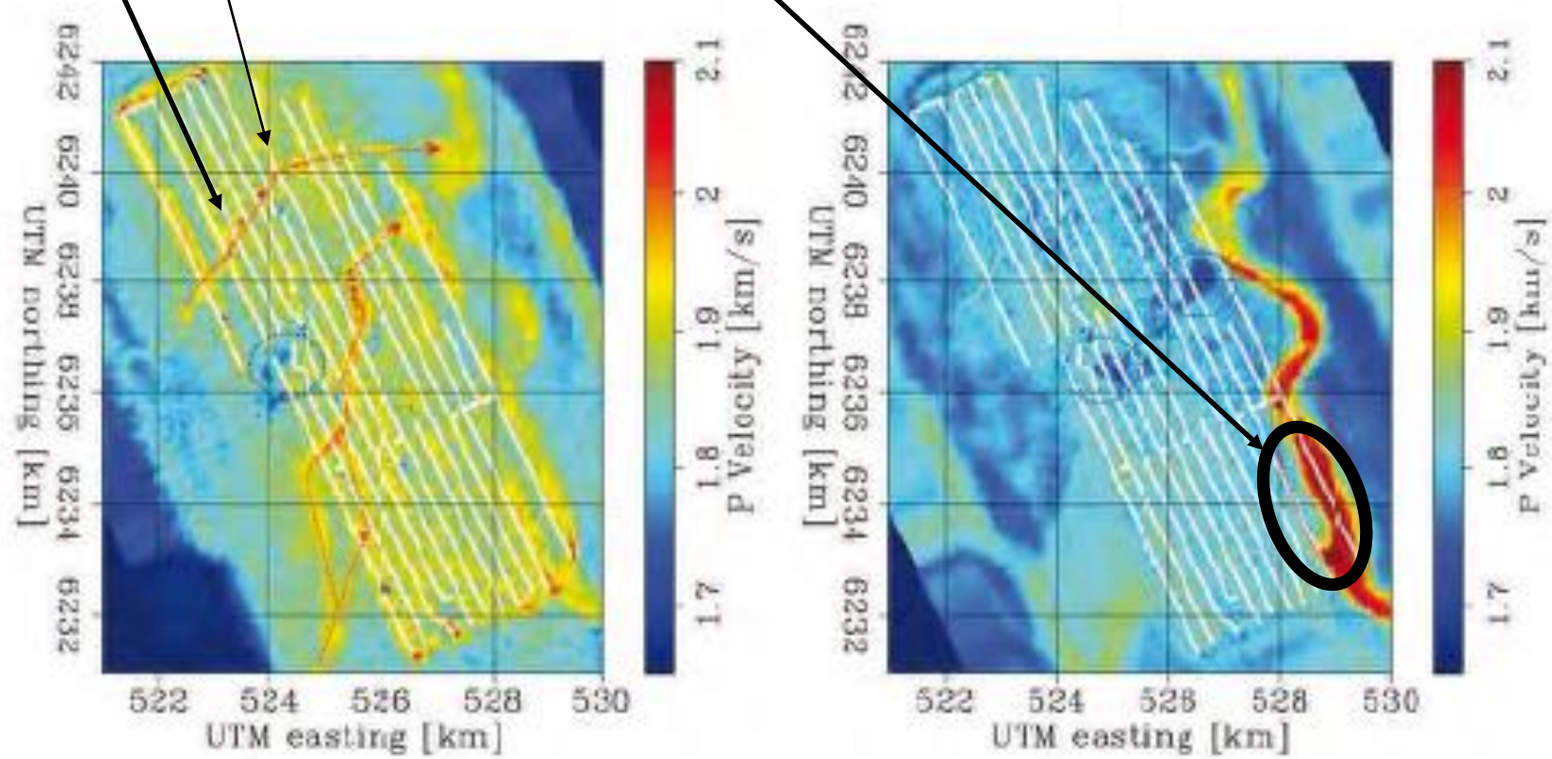
We observe paleo-channels buried in the subsurface

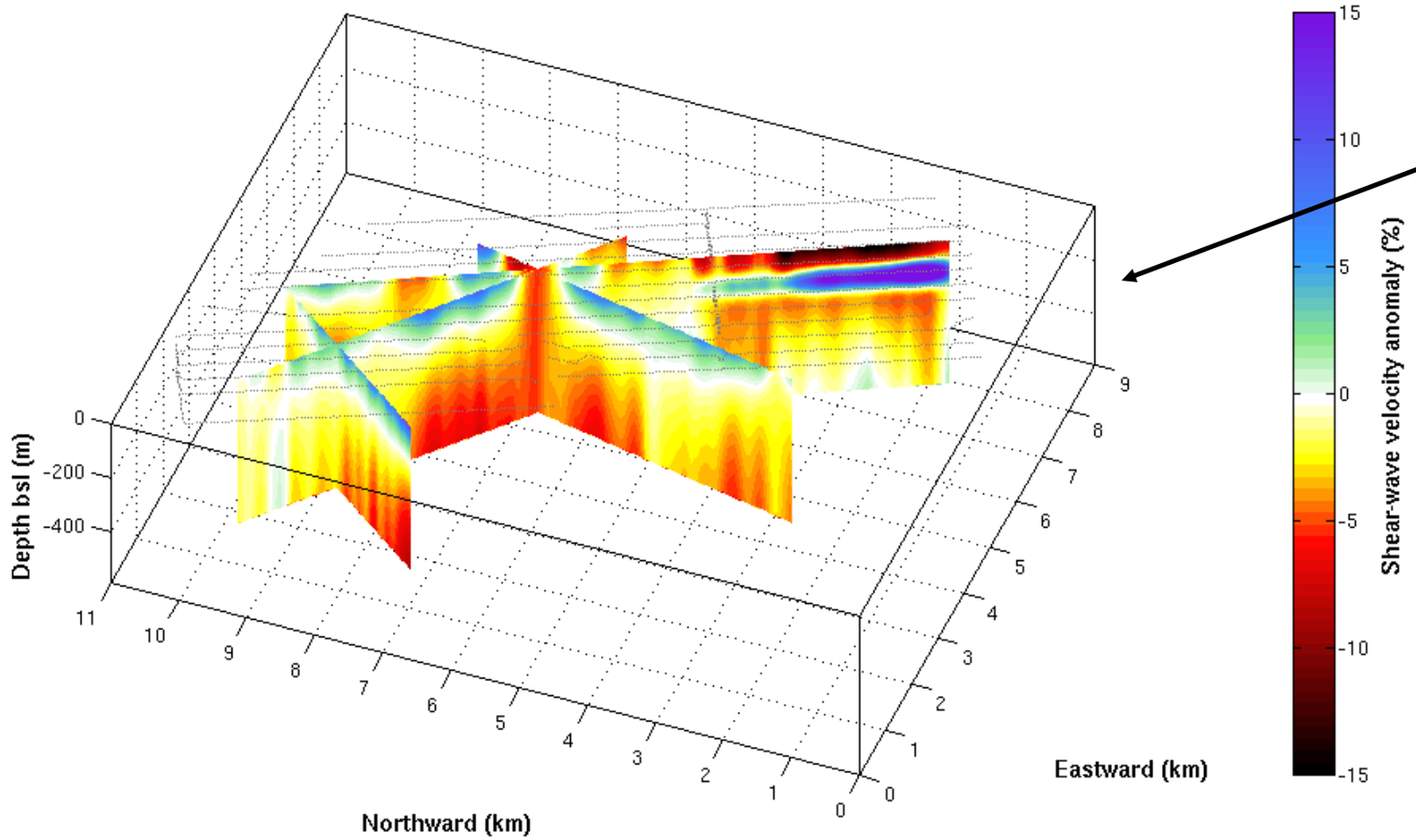
Our results using only 6.5 hours of seismic noise !!

Active seismic results using boats and explosions

(P-wave velocity)
Sirgue et al, (2010)

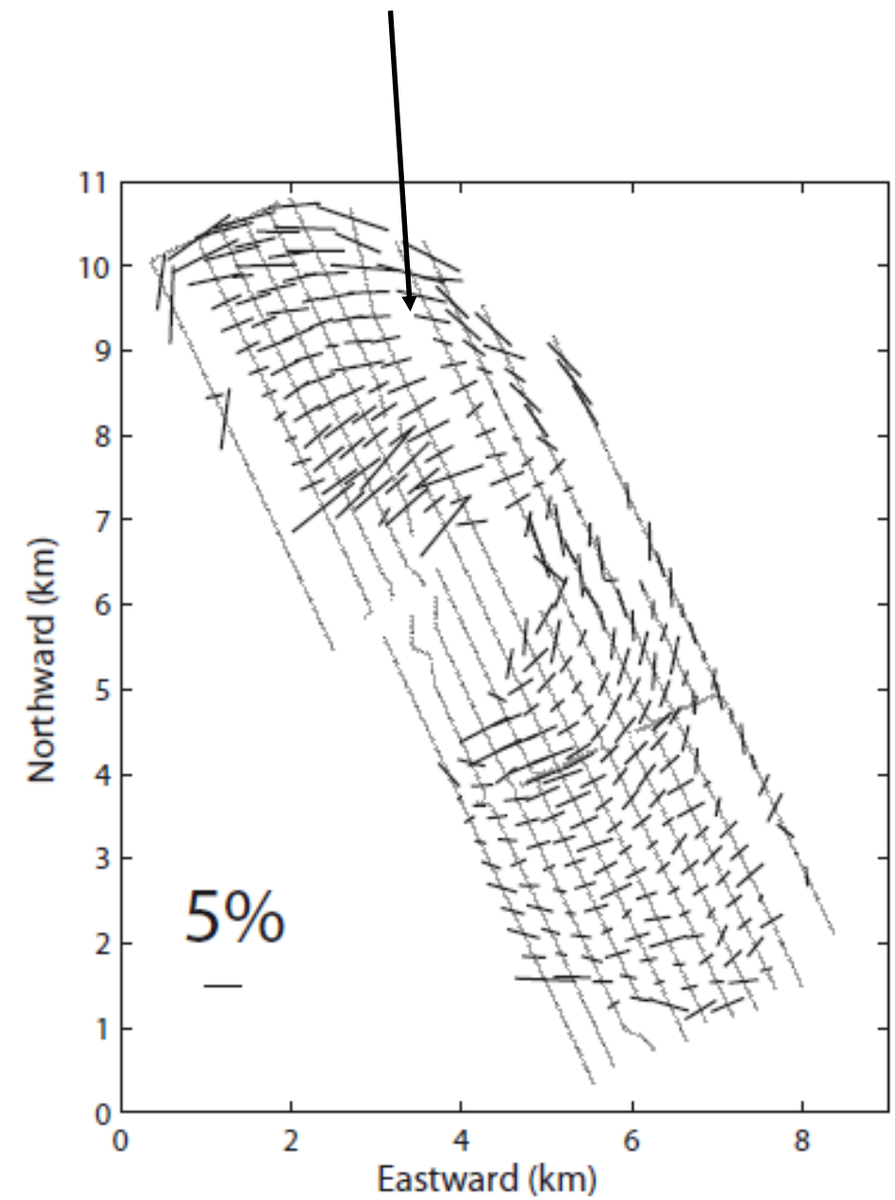






Possibility to create a 3-D velocity model

Possibility to detect the orientation of microfractures



Summary:

- 6.5 hr of seismic noise from 2320 seismometers
- ~ 25 million of correlations
- Computation on the European Grid facilities

- Creation of a high-resolution 3-D seismic velocity model of the near-surface showing different geological features

- Potential applications for inexpensive continuous monitoring of the near-surface above an oil reservoir