IFE14 seismic event identification
by spectral pattern recognition and combination of array and network localization

Benjamin Sick
Nicolai Gestermann
Martin Häge
Thomas Blake
Peter Labak
Manfred Joswig

1Institute for Geophysics, University of Stuttgart, Germany
2Federal Institute for Geosciences and Natural Resources, Hannover, Germany
3Schlumberger PetroTechnical Services, Calgary, Canada
4Dublin Institute for Advanced Studies, Geophysics Section, Dublin, Ireland
5Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria
Seismic Aftershock Monitoring System (SAMS)

- Detection of microseismicity related to collapses or aftershocks from underground nuclear explosions
- Deployment of 12 mini-arrays and 4 three-component stations
Challenges for SAMS during IFE14

Difficult deployment:
- Mountaineous terrain
- Security risks
- Sparse road network

Challenging data analysis:
- Abundance of local natural events from the Dead Sea Rift
- Man-made seismic events from local quarries

Topography in the Inspection Area.

Seismicity in the region since 2000 (Geophysical Institute of Israel).
Scenario events to test SAMS

- 3 near surface explosions on two consecutive days
  (Magnitudes $ML = 0.0; -0.2; -0.6$)

Locations of the scenario events near station SJ02.

1. event (yield 10 kg)
2. event (yield 5 kg)
3. event (yield 3 kg)
Manual event screening

Filtered seismograms show only few strong natural events.
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**Sonograms** (noise adapted spectrograms) allow the detection of additional natural events and the 2 weak scenario events.
Manual event screening

5 kg explosion

3 kg explosion

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Which automatic detection approaches can be used?

Detections at the 2 days with scenario events. Each dot represents the maximum detection level in a 60 second window. Scenario events in cyan, natural events filtered.
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- **STA/LTA at station SJ02** --- false positives: 10
- **Kurtosis at station SJ02** --- false positives: 26
- **Spectral pattern recognition at station SJ02, pattern from 1. explosion** --- false positives: 0
- **Spectral pattern recognition at station SJ02, patterns from AC2TC campaign 2011** --- false positives: 3

Detections at the 2 days with scenario events. Each dot represents the maximum detection level in a 60 second window. Scenario events in cyan, natural events filtered.
Which automatic detection approaches can be used?

STA/LTA at station SJ05 --- false positives: 84

Detections at the 2 days with scenario events. Each dot represents the maximum detection level in a 60 second window. Scenario events in cyan, natural events filtered.
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STA/LTA at station SJ05 --- false positives: 84

Spectral pattern recognition at station SJ05, pattern from 1. explosion --- false positives: 4

Detections at the 2 days with scenario events. Each dot represents the maximum detection level in a 60 second window. Scenario events in cyan, natural events filtered.
Which automatic detection approaches can be used?

- STA/LTA at station SJ05 --- false positives: 84
- Spectral pattern recognition at station SJ05, pattern from 1. explosion --- false positives: 4
- Spectral pattern recognition at station SJ05, patterns from AC2TC campaign 2011 --- false positives: 13

Detections at the 2 days with scenario events. Each dot represents the maximum detection level in a 60 second window. Scenario events in cyan, natural events filtered.
Manual localization of events with pick uncertainty

Sonograms at the top and filtered seismograms at the bottom of weakest scenario event. P (blue) and S (green) onset picks with assigned uncertainty in gray.
Grid search with uncertainty and topography constraints

Localization residuum map (darker color corresponds to smaller residuum) with array beam of station SJ03. Real location marked with a cross.
Grid search with uncertainty and topography constraints

Localization residuum map (darker color corresponds to smaller residuum) with array beam of station SJ03. Real location marked with a cross.

Localization constraints map including uncertainties (darker color corresponds to better fit of constraints).
Grid search with uncertainty and topography constraints

Localization constraints map including uncertainties (darker color corresponds to better fit of constraints).

Same as before but topography included as an additional location constraint.
Automatic localization by source-scanning

- Low SNR makes automatic phase picking impractical
- Source-scanning can provide a more robust solution:
  1. Iterate hypothetic event over geographic grid
  2. Stack characteristic function with theoretical travel time offsets for each hypothetical event

XY-grid of stack maxima from source-scanning with Kurtosis of weakest scenario event.
Manual and automatic localization of scenario events

Automatic localizations are comparable in accuracy to manual ones.
Conclusions

- Low-SNR events can be found even in seismically active areas with adapted processing techniques as e.g. sonograms.
- Conventional automatic detectors as e.g. STA/LTA produce too many false positive detections.
- Spectral patterns from previous campaigns can be used to detect events more reliably.
- Visualization of location constraints and inclusion of topography can improve localization accuracy.
- Source-scanning can be used to locate low SNR events automatically.

Outlook: Combination of source scanning with beam-forming and additional usage for detection.
Thank you for your attention

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Sonogram generation

Processing steps of sonogram calculation for a local earthquake ($M_L 1.0, 7.7$ km)
Super-sonogram compilation

- Combination of mini-array information to allow fast coherency checks and screening of multitude of mini-arrays

Super-sonogram compilation from the 4 sonograms of the vertical traces of a mini-array

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Influence of topography on beam-forming

Topography around station SJ02 (background color) and beam-forming without topographic contraints (ground truth marked with cross).
Influence of topography on beam-forming

Beam-forming with topographic constraints.
Station elevation test with synthetic waveforms

Comparison of localization without and with the use of station elevation (left and right column respectively). Top panels show an overview, bottom panels show the zoomed rectangle. The ground truth location is marked with a yellow cross. Color is according to residuum (white is low).
Source Scanning in varying depth

25km x 25km grid of source scanning with Kurtosis of weakest scenario event. Varying depth from 0 to 1 km.
Localization with NonLinLoc

NonLinLoc localization error ellipsoids of the 3 scenario events.
1st scenario event detectable at SJ02, SJ04 and SJ05 (filter 5-40 Hz), 10kg.
2. scenario event

2nd scenario event detectable at SJ02, SJ03 and SJ05 (filter 5-40 Hz), 5kg.
3rd scenario event detectable at SJ02 and SJ03 (filter 5-40 Hz), 3kg.