Migration-based Detection and Location of the Seismicity Induced at Rittershoffen Geothermal Field (Alsace, France)

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AGIS Workshop on Induced Seismicity
Davos Schatzalp, Switzerland
Rittershoffen geothermal field

- Upper Rhine Graben
- EGS field for process heat 24 MWth
- Doublet @ ~2.5 km depth
  - Triassic sandstone
  - Paleozoic granite
- 70 L/s / 160°C

Dec. 12: GRT1 drilled
Jun. 13: GRT1 stimulation
Jul. 14: GRT2 drilled (no stimul.)

(Baillieux, 2012)
Seismic network during GRT1 stimulation

Short period sensors
- 8 stations from Soultz permanent network (1C/3C)
- 4 stations from Rittershoffen permanent network (3C)
- 5 stations from KIT temporary network (3C)

△ Before water stimulation of GRT1
GRT1 stimulation induced seismicity

Preliminary (semi-)automatic results

*(Obtained using SeisComp3)*

- 174 events during stimulation
- 37 events 4 days later
- Max. $M_{LV} = 1.3$ during / 1.6 after

- Cloud close to BoH
- Centre deeper than BoH
- ~ 1 km EW x 2 km NS x 2 km Z
Motivation

- > 100 event/hr
- Saturation of real-time manual processing
Motivation

- > 100 event/hr
- Saturation of real-time manual processing

⇒ Test a network-based automatic detection and location technique
⇒ Calibrate it / Compare it with exhaustive manual (post-)processing

~900 events in 6 hours
Waveloc description

- Applied to the Piton de la Fournaise Volcano (Langet et al., BSSA, 2014)
- Automatic kurtosis-based migration detection and location technique

1. Pre-processing
   - Raw channel filtering
   - Detection function computation: Kurtosis

2. Migration
   - Move-out correction
   - Stack
   - Store $\max_{XYZ}(t_i)$

3. Detection Location
Present application of Waveloc

- P-wave only

- Velocity model
  - 1D layered
  - Obtained from 0VSP

- Database
  - 15 Z-components
  - 27 Jun 14:30 – 20:30
    - Exhaustive manual processing (857)
Data pre-processing

Objective:
- To enhance P-wave arrivals on each channel
- To tune the kurtosis calculation

(a) 6000 -
(b) 5000 -
(c) 4000 -
(d) 3000 -
(e) 2000 -
(f) 1000 -
-5000 -
5 10 15 20 25 30 4 5 10 15 20 25 30 5 10 15 20 25 30 0 1 2
Time (s)
Time (s)
Time (s)
Amplitude (counts)
Amplitude (counts)
Amplitude (counts)

KUHL

Level 2.0, Bw=12.50 Hz, fc=31.25 Hz

Amplitude (counts)

Frequency (Hz)

Level k

0.0 1.0 1.6 2.0 2.6 3.0 3.6 4.0
0 5 10 15 20 25 30 35 40 45
0 4 8 12 16 20 24 28

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Migration-based detection and location - E. Gaucher et al.
Data pre-processing

- Raw – Filtered – Kurtosis – Gradient of kurtosis

⇒ Gradient of kurtosis better indicator of first arrival
⇒ 500 ms window less dependent on event amplitude
Event detection

- Criteria
  1. Threshold on migrated trace for a given number of stations (7)
  2. SNR on filtered trace (3)
  3. SNR on kurtosis trace (4)

- Comparison with manual
  - Dt < 0.3 s

- Example
  - Detected: 137
  - Common: 100
  - 73% good detections
  - 12% of manual events
Event detection

(a) Data

(b) Characteristic function

2013-06-27T15:30:23.610000

2013-06-27T:5:30:23.610000 x = 1010.54km y = 2448.00km z = 2.54km

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Noticeable discrepancies with manual processing

Waveloc location uncertainties
- Median: 400 m / 200 m / 500 m
  - East
  - North
  - Depth
Detection & Location variations

- **Case 1 (red)**
  - Threshold = 4 x median
  - 73% good detections
  - 12% of manual events

- **Case 2 (blue)**
  - Threshold = 5 x median
  - 85% good detections
  - 10% of manual events

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**Occurrence time discrepancies**

- Case 1 (red): Threshold = 4 x median
  - 73% good detections
  - 12% of manual events

- Case 2 (blue): Threshold = 5 x median
  - 85% good detections
  - 10% of manual events
Conclusions & Perspectives

- No migration-based locations provided yet
- Automatic processing needs calibration
  - Needs manual processing
  - Needs time

- Migration-based methods are strongly dependent on velocity models
  - Introduction of station correction?

- Application using a denser network
Seismic network before drilling of GRT2

Short period sensors

- 8 stations from Soultz permanent network (1C/3C)
- 4 stations from Rittershoffen permanent network (3C)
- 31 stations from KIT temporary network (3C)

△ Before water stimulation of GRT1
△ Before hydraulic tests of GRT1
△ Before drilling of GRT2

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Thank you!