Rapid and automated full seismic source characterization: seismic monitoring application for the North Korean region

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North Korea is the lone country to have performed nuclear tests in the 21st century

Moment tensor inversions helped to identify the source of the DPRK events

Development and implementation of an interactive tool

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO.
Several approaches are considered in order to detect and characterize seismic events, including nuclear explosions. More often a cascade-like procedure is used:

- Moment tensor (MT) inversion provides information about the magnitude of an event, and its mechanism.
- MT inversions are often done by a senior seismologist (expert).
- Generalize MT inversions for source characterization, in a rapid and easy-to-use algorithm: earthquake monitoring, tsunami monitoring, nuclear explosion monitoring.
GRID MT: Grid-based Realtime Determination of Moment Tensors (Kawakatsu, 1998)

Based on a continuous inversion of seismic records filtered at long-period over a grid of point sources

Advantages
- **Rapid**: pre-calculated Green’s functions, pre-determined inversion parameters
- Requires a limited number of seismic stations
- **Provides all source information**: origin time, location (lat, lon, depth), Mw, mechanism, source decomposition
- **Unique algorithm applicable to natural/explosive sources**

Limitations
- **Fixed grid, fixed number of stations**
- **Important work of MT parametrization**: frequency band, window length, etc

Usable for earthquake monitoring and for other types of seismic events, including large earthquakes (A. Dupont, P5.2-582) and nuclear explosions

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**Goal:**
Detect and characterize any artificial and shallow events occurring in North Korea

- **Successful moment tensor inversions for past DPRK events using regional stations (Guilhem Trilla, SnT 2017)**
- Selection of 4 IRIS regional stations distributed around the Punggye-ri test site
- Focus on shallow sources → 2D grid covering North Korea fixed, at 1 km fixed depth
- 1D velocity model
- **Full moment tensor inversion**
- Continuous waveforms filtered at long-period
- Peak value in the inversion’s misfit function (here, variance reduction VR) gives the source characterization (OT, location, Mw, mechanism)
Example of the September 2017 nuclear test in North Korea

**RESULTS**

- **DPRK 6**
  - **Collapse**
  - **GRiD MT**

Two events: nuclear test followed by an induced event (collapse)

Map view of the GRiD MT results

- Best VR value found near the Pynggye-ri test site (star)

- One main VR peak corresponding to the Mw5.6 nuclear test (explosion) followed 8min30 later by a smaller size event (Mw4.8) corresponding to an implosive source
RESULTS

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Solution from GRiD MT

Manual solution

DPRK 6

MDJ

Distance = 373 km Azimuth = 8 Max Amp = 2.73e–03 cm Zcorr = 1 VR = 8

INCN

Distance = 468 km Azimuth = 206 Max Amp = 2.28e–03 cm Zcorr = 1 VR = 8

MAJO

Distance = 964 km Azimuth = 120 Max Amp = 1.20e–03 cm Zcorr = 1 VR = 56

BJT

Distance = 1085 km Azimuth = 267 Max Amp = 1.26e–03 cm Zcorr = 1 VR = 68

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- Implementation allowing the detection and characterization of all past DPRK nuclear tests with large variance reduction values (VR)
- Lower VRs for other types of regional events

Guilhem Trilla and Cano, SnT 2017

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**RESULTS**

**DPRK 6**

- Implementation allowing the detection and characterization of all past DPRK nuclear tests with large variance reduction values (VR)
- Lower VRs for other types of regional events

**Solution from GRiD MT**

- Manual solution
- Solutions in good agreement

**Example of the Mw 5.5 in South Korea (12 September 2016)**

Grid @ 12 km depth

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CONCLUSIONS

- GRiD MT is an interesting approach for seismic event detection and characterization
- Unique algorithm as opposed to a suite of algorithms
- Provides OT, location, Mw, mechanism, source decomposition
- Good performances for past DPRK events with only 4 stations

- Rapid: results obtained within only a few minutes
- Implementation of an interactive tool usable by the seismic analyst at CEA