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

Aurélie GUILHEM TRILLA

P2.1-371

POSTER

aurelie.trilla@cea.fr

CEA, DAM, DIF, F-91270 Arpajon cedex, FRANCE

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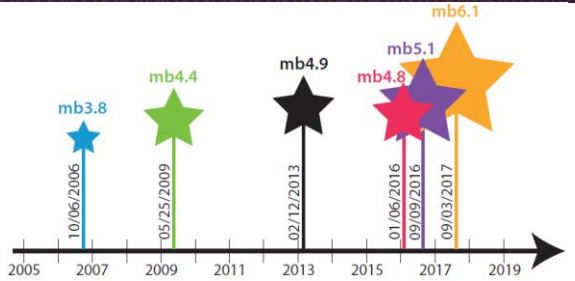
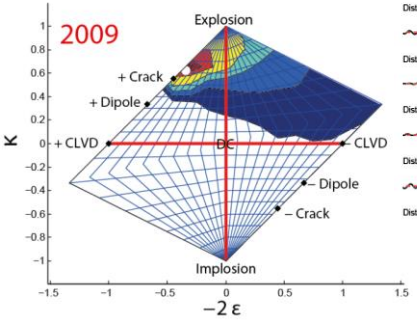
ABSTRACT

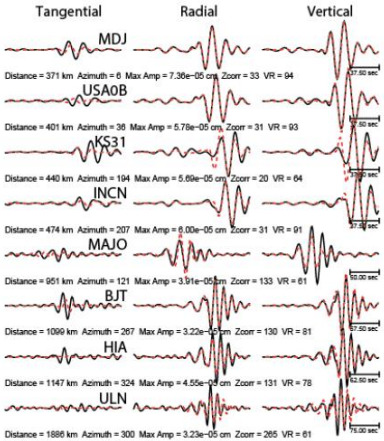
North Korea is the lone country to have performed nuclear tests in the 21st century

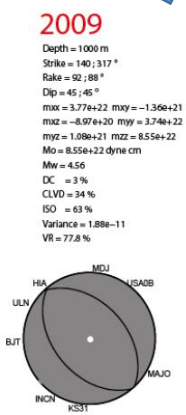


Moment tensor inversions helped to identify the source of the DPRK events

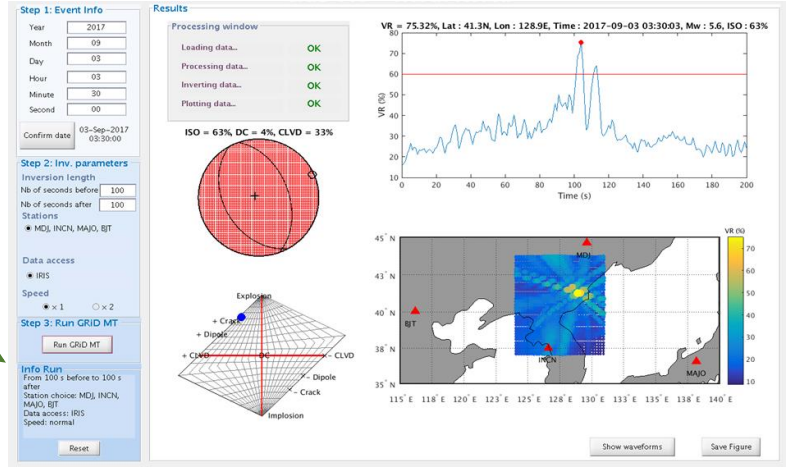


Guilhem Trilla and Cano, SnT 2017





Development and implementation of an interactive tool



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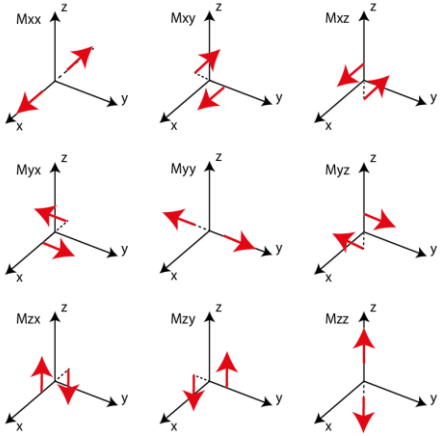
INTRODUCTION

- 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

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METHODS

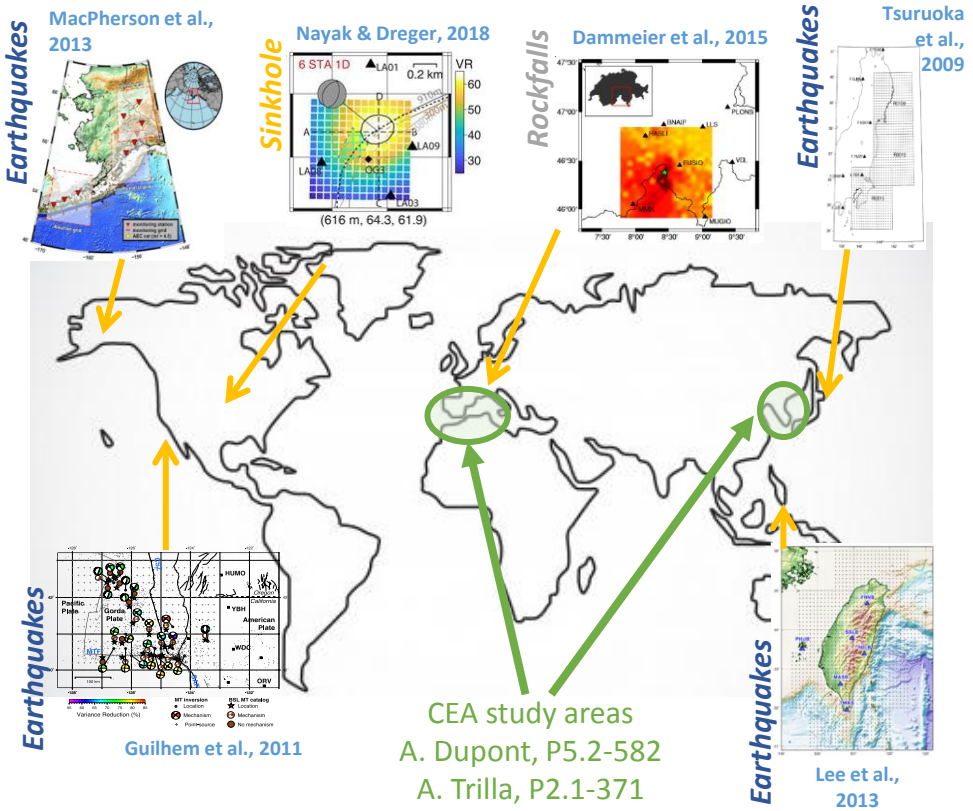
- **GRiD MT**: Grid-based Realtime Determination of Moment Tensors (Kawakatsu, 1998)

- 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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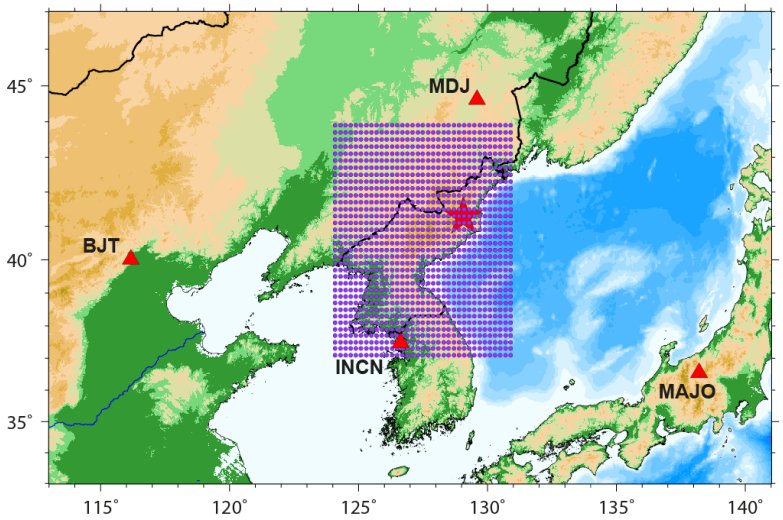
METHODS

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)

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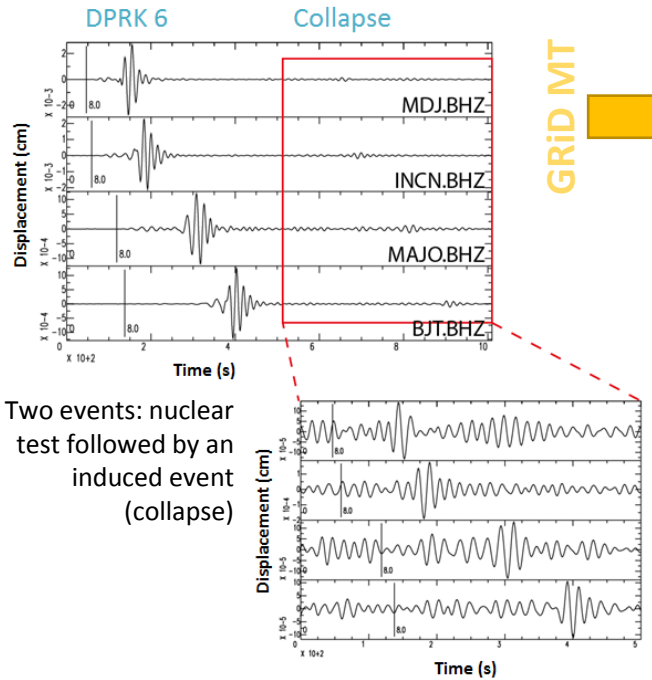
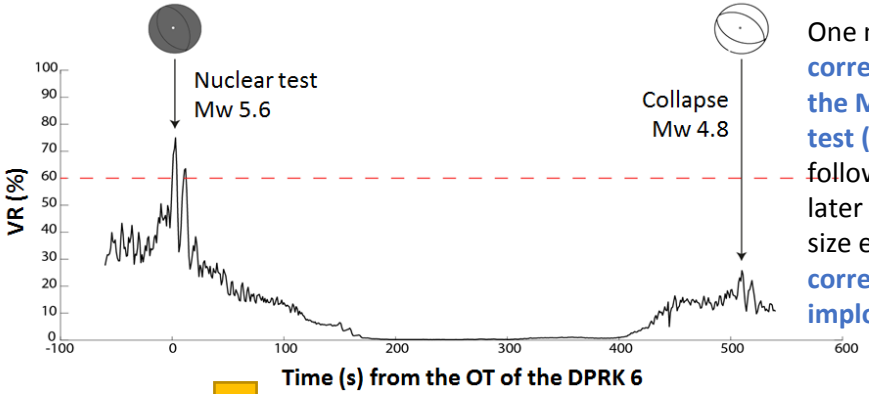
RESULTS

Example of the September 2017 nuclear test in North Korea

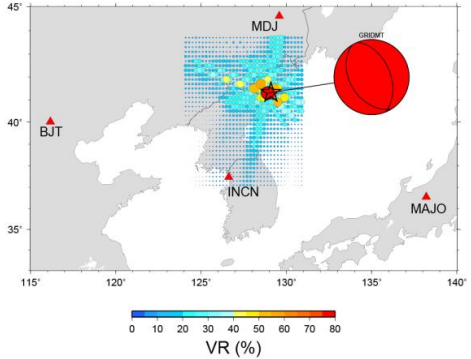


Two events: nuclear test followed by an induced event (collapse)

GRiD MT



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**



Map view of the GRiD MT results

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

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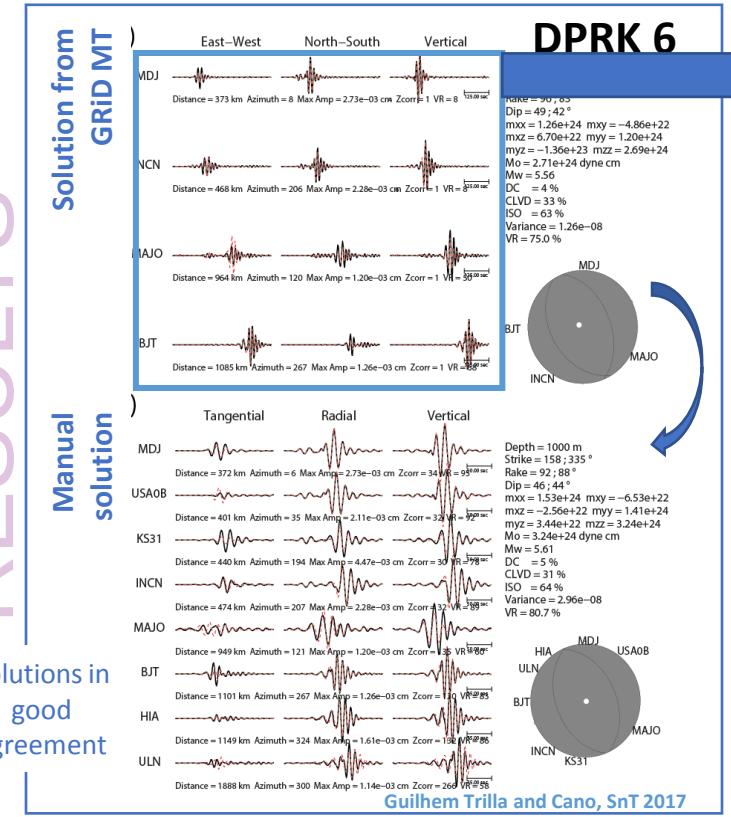
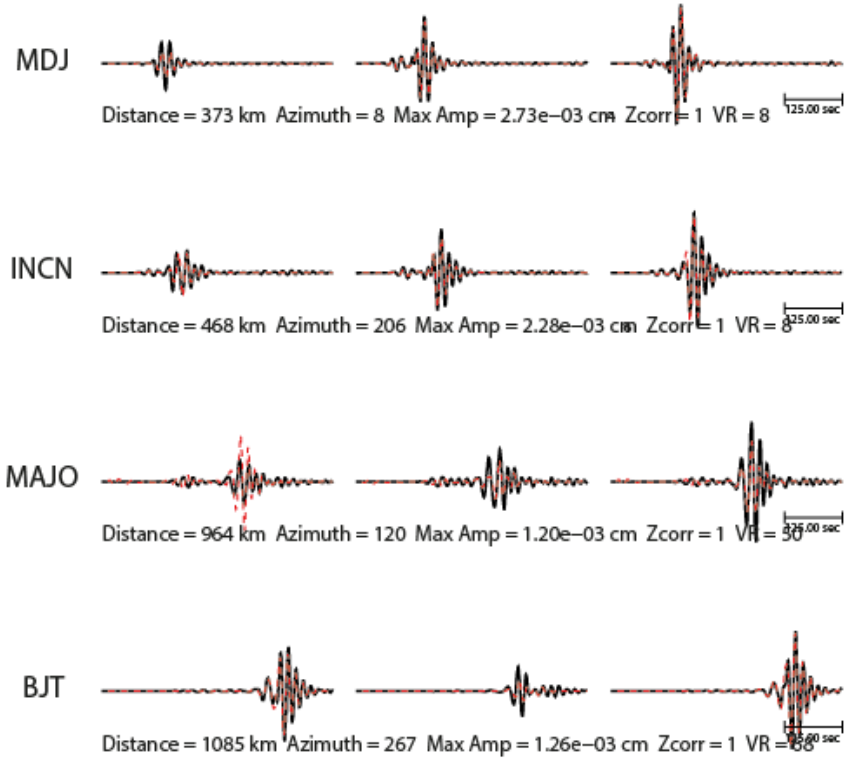
RESULTS

Solutions in good agreement





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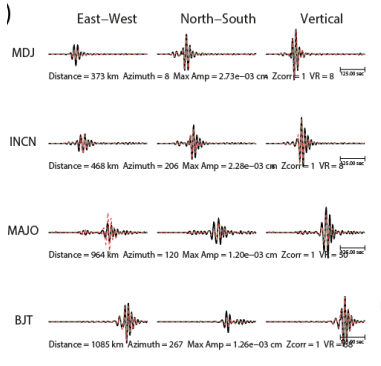
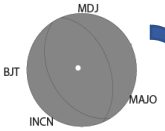
RESULTS

DPRK 6

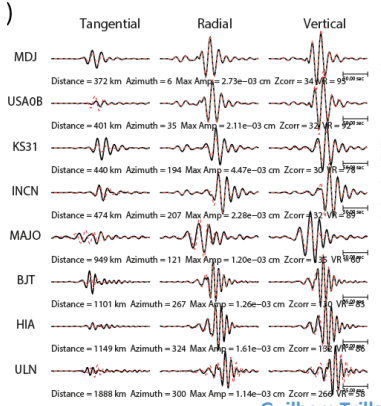
Solution from GRiD MT



Depth = 1 km
Strike = 338 ; 148 °
Rake = 96 ; 83 °
Dip = 49 ; 42 °
mxx = 1.26e+24 mxy = −4.86e+22
mxz = 6.70e+22 myy = 1.20e+24
myz = −1.36e+23 mzz = 2.69e+24
Mo = 2.71e+24 dyne cm
Mw = 5.56
DC = 4 %
CLVD = 33 %
ISO = 63 %
Variance = 1.26e−08
VR = 75.0 %



Manual solution



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mxz = −2.56e+22 myy = 1.41e+24
myz = 3.44e+22 mzz = 3.24e+24
Mo = 3.24e+24 dyne cm
Mw = 5.61
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CLVD = 31 %
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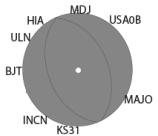
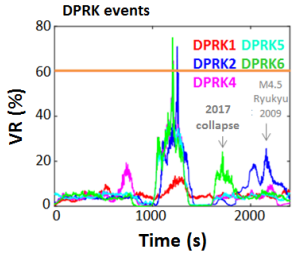
Variance = 2.96e−08
VR = 80.7 %

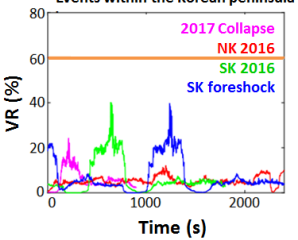


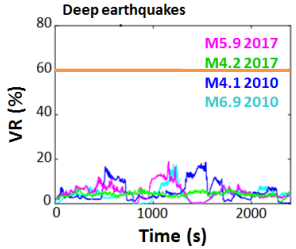
Guilhem Trilla and Cano, SnT 2017

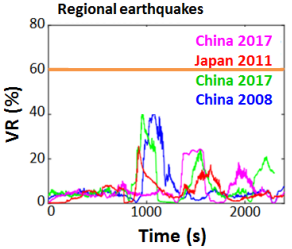
Solutions in good agreement

- 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









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RESULTS

DPRK 6

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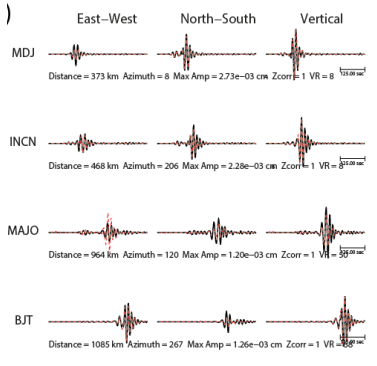

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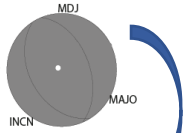
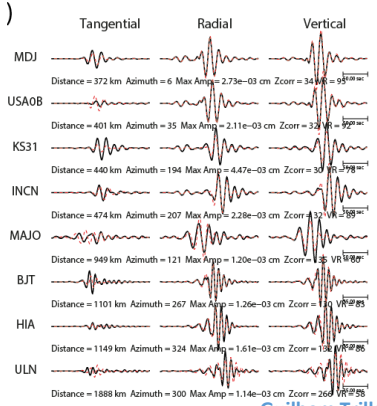


Manual solution



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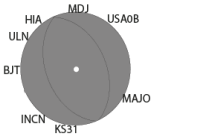

Solutions in good agreement

Guilhem Trilla and Cano, SnT 2017

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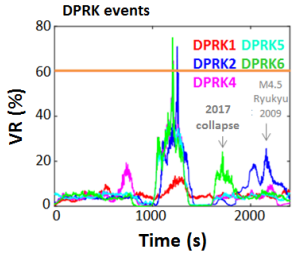

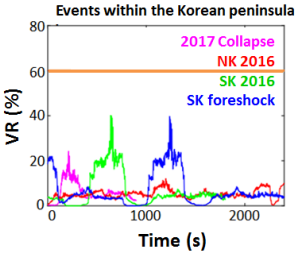

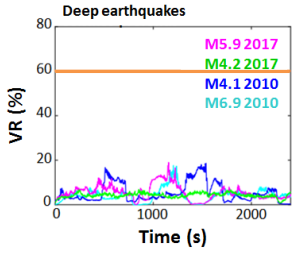

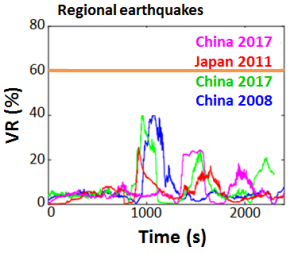

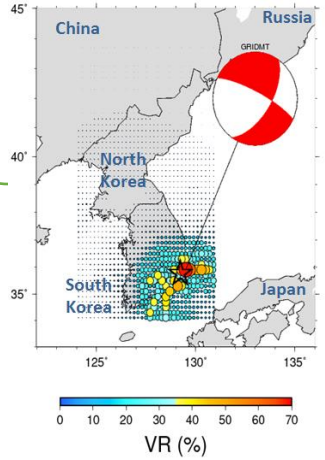

Earthquake monitoring

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

Grid @ 12 km depth

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO

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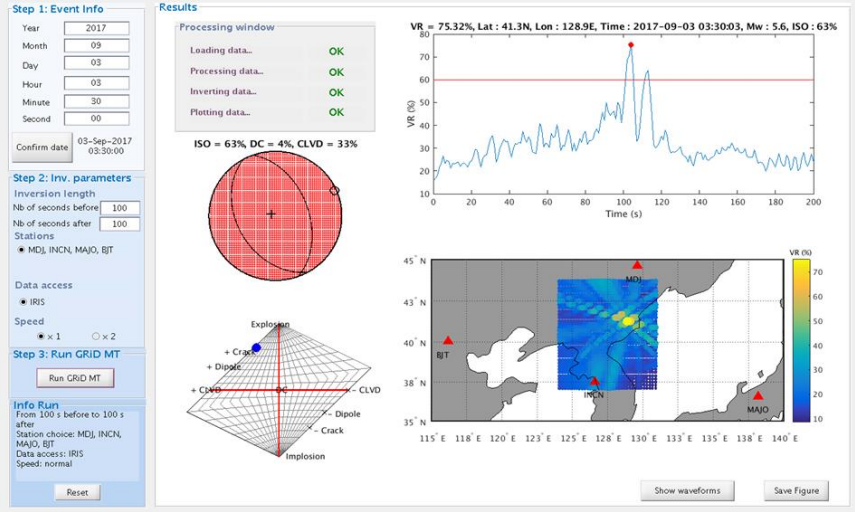
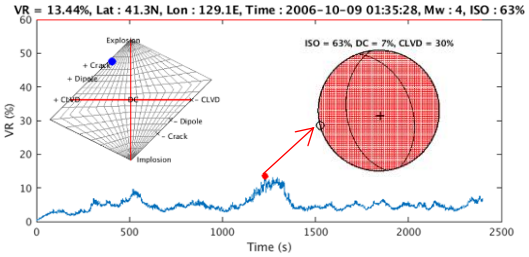
CONCLUSIONS

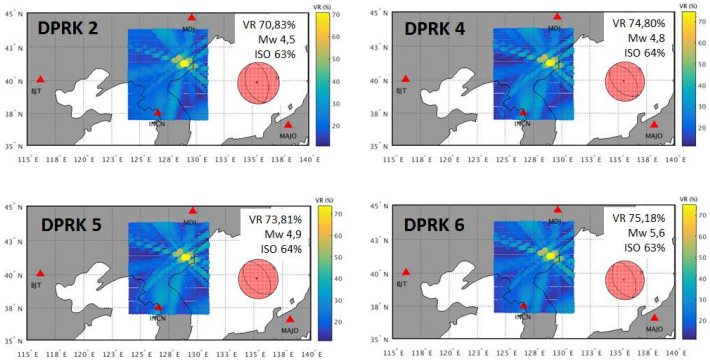
- GRiD MT is an interesting approach for seismic event detection and characterization
- **Unique algorithm** as opposed to a suite of algorithms
- Provides OT, location, Mw, mechanism, source decomposition

- Good performances for past DPRK events **with only 4 stations**



DPRK 1





Station INCN missing for DPRK 3

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