DE LA RECHERCHE À L'INDUSTRIE

Toward implementing a grid search moment tensor (GRiD MT) tool for the rapid detection and characterization of seismic events in Metropolitan France

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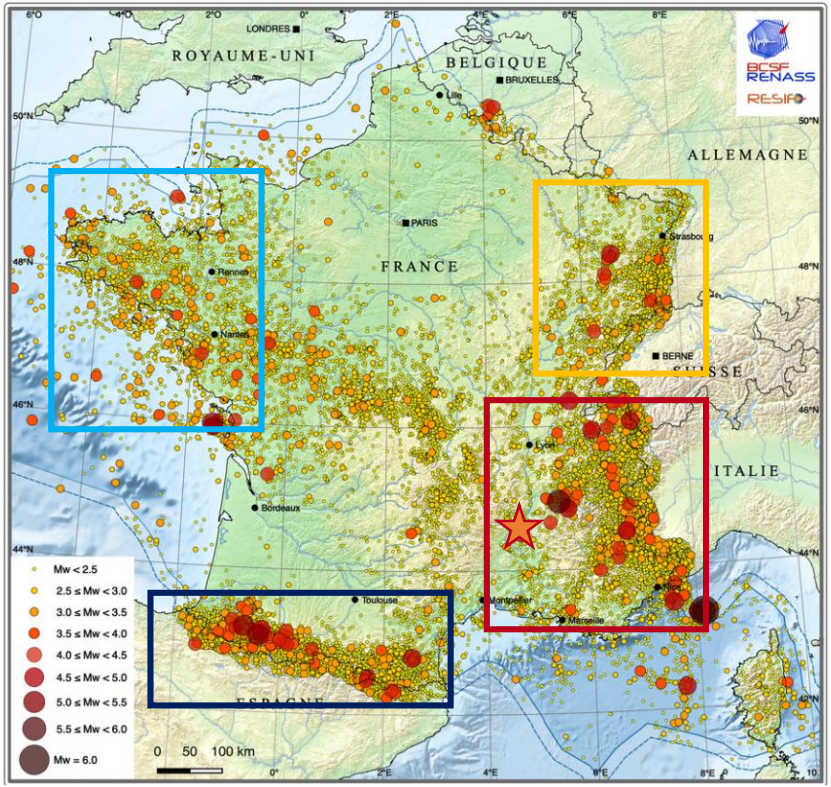


Instrumental seismicity in metropolitan France 1962-2018

- Seismic monitoring of metropolitan France
- Weak to **moderate seismicity** (up to magnitude of 6.5)
- Particular interest in seismic events with magnitude between 3.5 and 6.5

★ Le Teil earthquake ML 5.4 2019/11/11

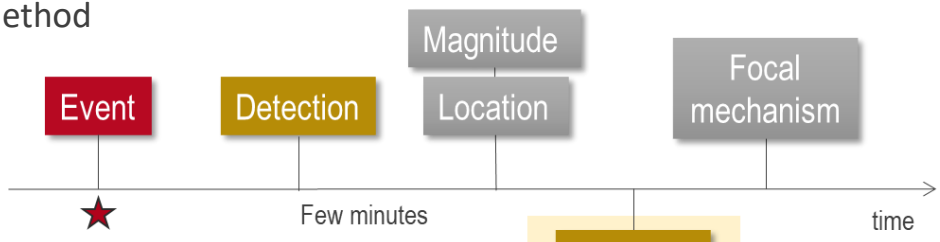
- First tests for South-Eastern France

GRID MT METHOD

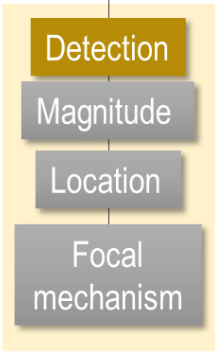
- GRiD MT: Grid Real-time Determination of Moment Tensor (Kawakatsu, 1998 and Tsuruoka et al., 2009)

- Grid search moment tensor
- Real-time and automatic method

Typical Event Characterization
→ Cascade approach

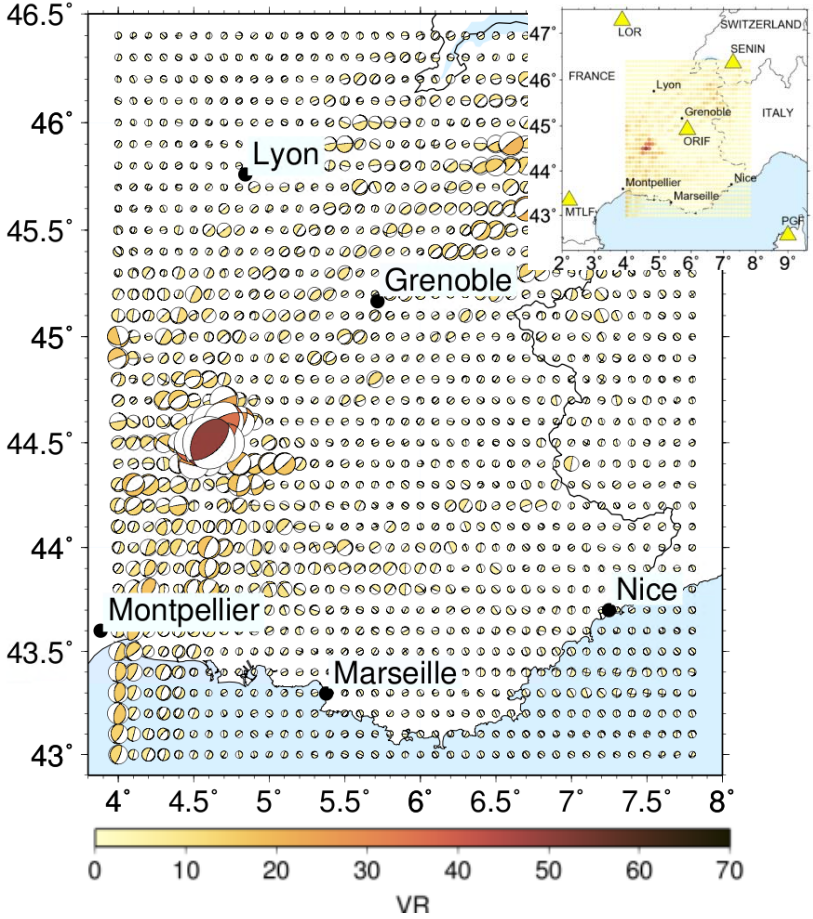


- Continuous data scan from a limited number of stations
- Causal bandpass filter
- Continuous TDMT inversion (Dreger, 2003) for each point of the grid
- Waveform misfit evaluated through variance reduction (VR)
- Detection and determination of optimal solution based on VR



GRiD MT approach
→ Unique algorithm

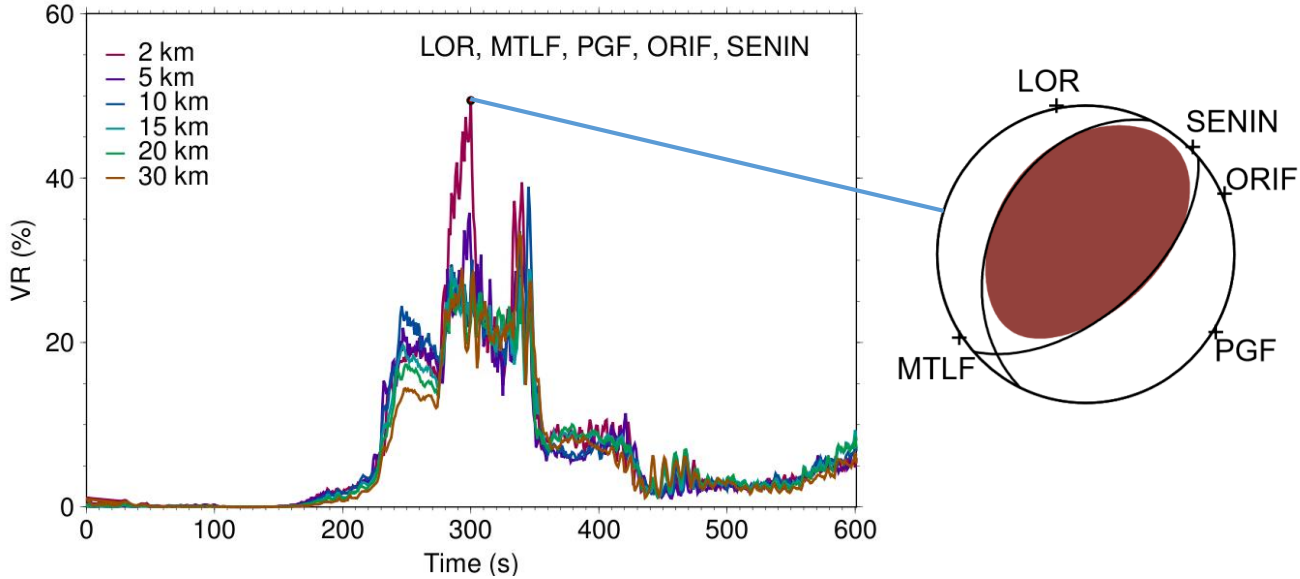
GRID MT METHOD



- **Preselected** parameters (stations, filters, velocity model, grid points)
- Limited parameters (number of stations, size of the grid)
- **Precomputed** Green's function
  → **time efficiency**

- Limited parameters (number of stations, size of the grid)
  → **storage efficiency**

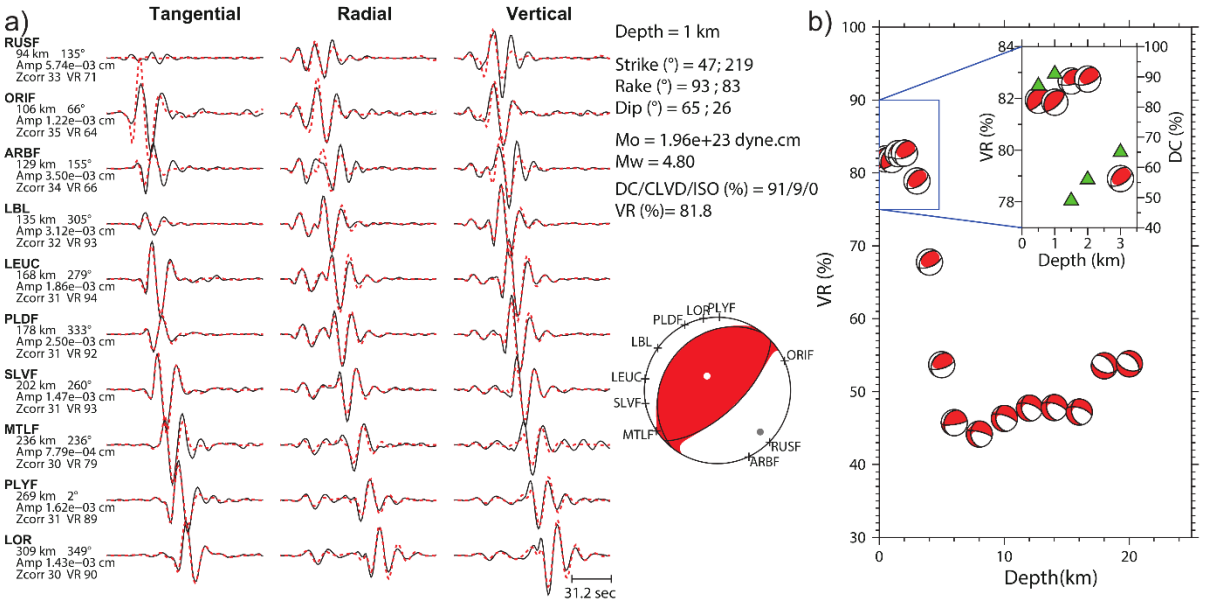
- Possible second peak depending on the bandpass period
  - Test to lower the second peak value (number of stations, station distribution, …)



Maximum VR value at a given time and depth, for any location of the grid

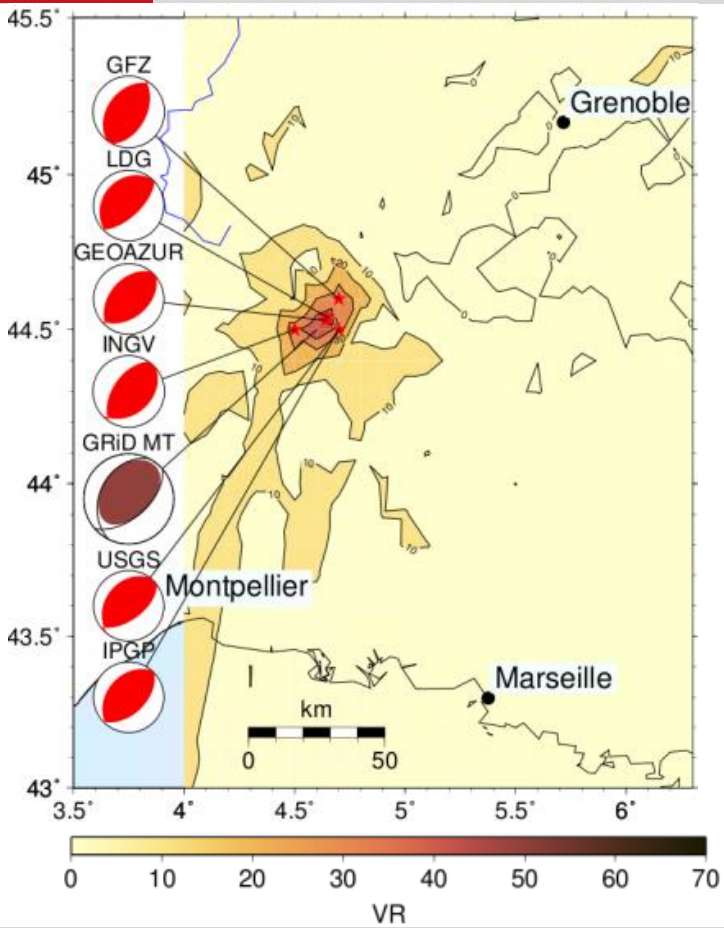
- Detection: VR value higher than a chosen threshold, for example 40 %
- Optimal solution: focal mechanism, origin time, magnitude and location associated with the first maximum VR value

CEA/LDG RESULTS - LE TEIL 2019



LDG solution, 10 stations (Vallage et al., GJI 2021)

- TDMT inversion (Dreger, 2011) for the origin time and the location determined by the CEA, and using 10 broadband regional stations
- Stations selected with high values of Variance Reduction (VR) and different azimuths to better constrain the focal mechanism
- TDMT inversions for different depths to determine the optimal depth corresponding to the one associated with the **highest VR value and double-couple component value (DC)**
- The optimal solution depth is 1 km



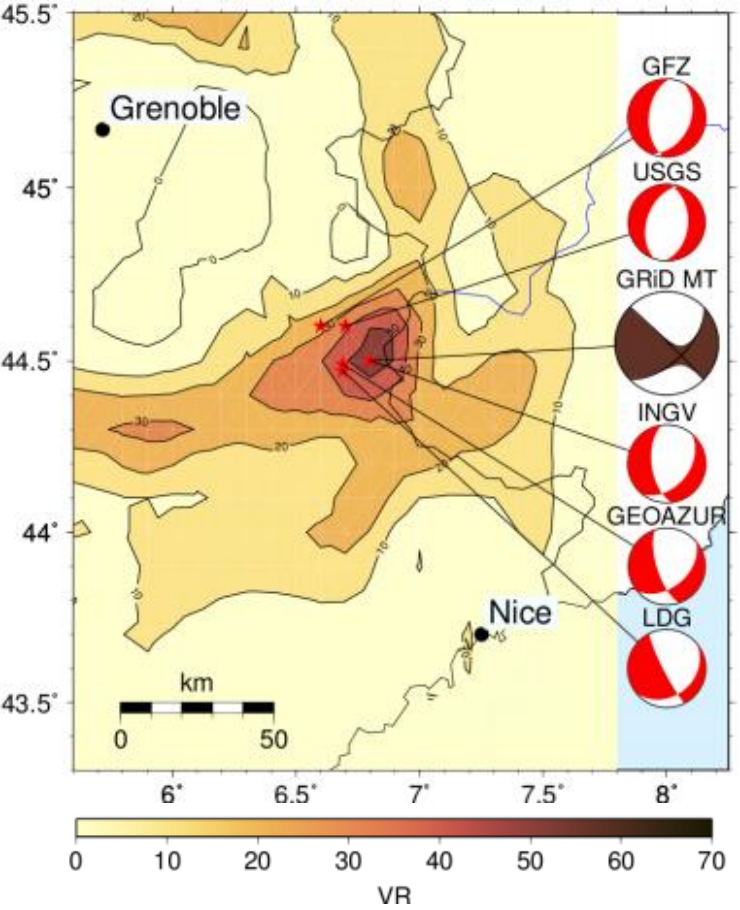
- ML 5.4 earthuake on 2019/11/11

- Results with 5 preselected broadband regional stations
  RD.LOR, RD.MTLF, RD.PGF, RD.ORIF, CH.SENIN
- Causal bandpass filter 0.03-0.08 Hz
- 1-D Earth model with 3 layers

- Similar focal mechanism: 83.80 % with the LDG solution (Kanamori and Rivera, 2014)
- Similar location: < 6 km distance from the LDG location
- Same magnitude: Mw 4.8
- Same origin time: 10h 52min 45s
  - Close proximity to solutions from other agencies

GRiD MT results for Le Teil 2019 event and published focal mechanism solutions (from EMSC)

PRELIMINARY RESULTS - BARCELONETTE 2014



- ML 5.3 event on 2014/04/07

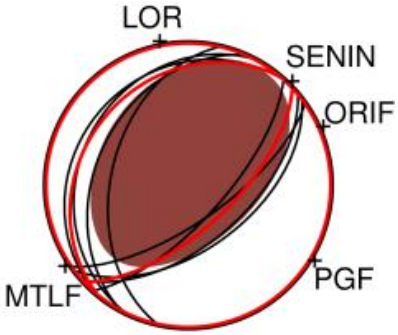
- Results with 4 preselected broadband regional stations
  - RD.LOR, RD.MTLF, RD.PGF, RD.ORIF
- Causal bandpass filter 0.03-0.08 Hz
- 1-D Earth model with 3 layers

- Focal mechanism slightly more strike-slip than other solutions
- Same location as INGV and within 10 km radius from LDG and Geoazur solutions
- Mw 5.0 → 0.1 magnitude unit larger than INGV, GFZ and LDG
- LDG Origin Time + 1 s
  - Source parameters well recovered overall

GRiD MT results for Barcelonnette 2014 event and published focal mechanism solutions (from EMSC)

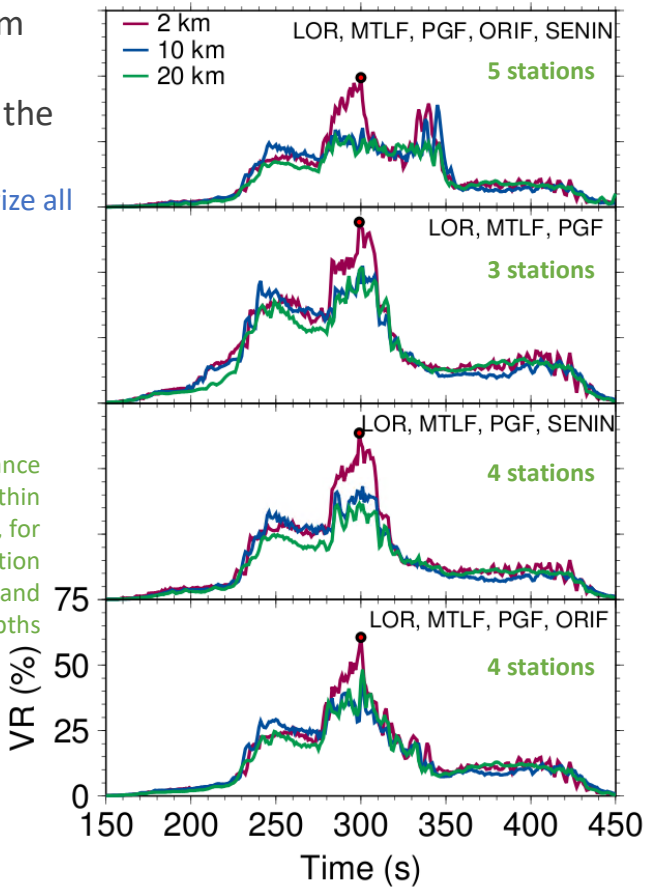
EFFECT OF THE STATION DISTRIBUTION

- Station coverage constrains the focal mechanism (FM) and the location
- Use of more stations increases the storage and the computation time, and decreases the VR value
  - Determination of a compromise to best characterize all events within the grid



Le Teil focal mechanisms with different station distributions (Red: LDG solution, 10 stations)

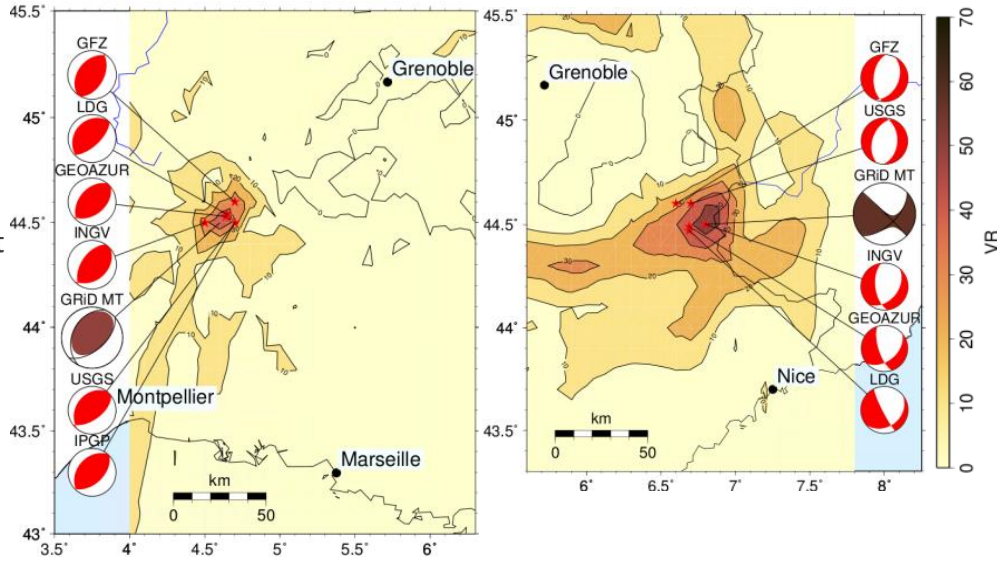
Maximum Variance Reduction Values within the grid against time, for different station distribution and different grid depths



- Stable mechanisms
- Stable detection: all VR maxima at 2 km depth (higher than at 10 and 20 km depth) and origin time (OT ± 1 s)

UNCERTAINTIES ON THE SOURCE PARAMETERS

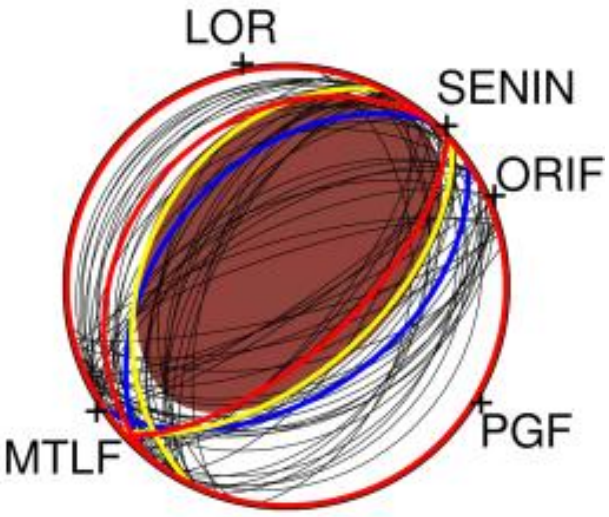
- Location well constrained
- For example, when taking a VR threshold of 30 %
  - All the point sources at OT with a VR > 30 % **form an ellipse of uncertainty** for the location of the hypocenter
  - All published location are located within the ellipse
  - True for the 2 events



Le Teil 2019 and Barcelonnette 2014 results with published solutions (from EMSC)

- The size of the ellipse depends on the number of stations and on the station distribution
  - **Work in progress**
  - Test on the number of stations and the station distribution to lower the uncertainties
  - Test to confirm the VR as an event detector to determine the location and the source parameters

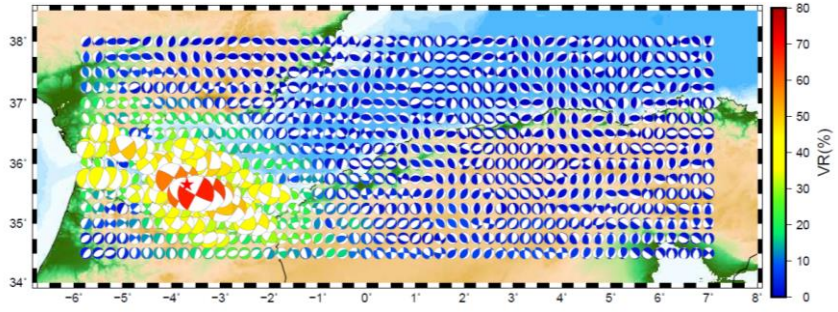
- For example, by taking the previous VR threshold (30 %), all the focal mechanisms at OT ± 5 s with a VR larger than the threshold, we can compute the uncertainty from the variability of these focal mechanisms
- The average focal mechanism (blue), obtained from all the focal mechanisms with VR > 30 %, is similar to the optimal GRiD MT (yellow) and the LDG (red) solutions
- But some of the VR > 30 % focal mechanisms (black) are somehow quite different
  - **Work in progress**
  - Test on the number of stations and the station distribution
  - Test on the VR threshold
  - Test to confirm the VR as an event detector to determine the location and the source parameters



Le Teil Focal Mechanisms (FM)
Black: FM with +30% VR values and OT ± 5 s
Blue: average FM
Yellow: Optimal GRiD MT solution
Red: Reference solution (LDG, 10 stations, Vallage et al., GJI 2021)

DISCUSSION

- The method is being validated for earthquakes with magnitude larger than 4
- A similar approach is presently implemented for larger events (M6.5) in the Western Mediterranean region (Guilhem Trilla et al., 2019)



GRiD MT approach for the Al Hoceima earthquake Mw 6.4 2016/01/25

- Work in progress
- For smaller magnitudes, parameters need to be adjusted (grid, filtering…)
- Test of additional station combinations and source detector in order to implement an optimized near-realtime source algorithm
- Use of synthetic tests to determine the efficiency of the method in areas where recent earthquakes are missing.
- Same approach for other regions in metropolitan France

- Please send me a message to marine.menager@cea.fr for additional questions

THANK YOU !