A consistent and uniform research earthquake catalog for the AlpArray region: preliminary results

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\url{www.alpararray.ethz.ch}
The Alps are a unique natural laboratory where we can advance our understanding of orogenesis and its relation to present and past mantle dynamics. This is the most studied mountain belt, now being monitored at unprecedented resolution.

A European collaborative project with the ambition to re-evaluate the dynamics of the Alpine-Mediterranean orogenic system.

The first realistic idea of this project goes back to 2010 (maybe earlier)

What is AlpArray

www.alparray.ethz.ch
Scientific goals

General and locally specific orogenic processes of Alpine-N Dinarides-N Apennines systems

Seismicity and seismotectonics, and seismic hazard in greater Alpine region

- linkage between orogenic evolution of Alps and N Apennines: mantle flow, roll-back slab dynamics and orogenic growth
- link between roll-back slab dynamics, crustal convergence, evolution of topography
- Improved earthquake catalogues
AlpArray: numbers

- More than **54 institutes** joined AlpArray Scientific Program.
- AlpArray officially started on **January 1th 2016**
- Research projects involves > **100 scientists**

- Many national projects related to AlpArray now supports PhDs and Post-Doc in Europe (Germany, Austria, France, Switzerland, Czech republic, Hungary, ... )
Total of ~600+ BB stations within 250km of 800m altitude of Alps (300+ permanent and 260+ temporary stations) in addition 20+ OBS in Ligurian sea operated starting from middle 2017
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- The **AA Seismic Network** is an effort of ~26 institutes in Europe
- > **100 people** involved in the temporary stations deployment
Motivation for the earthquake research catalog

- National and regional bulletins often report the same earthquake with different location and magnitude.
- Phase misidentification, non-uniform quality assessment, differences in picking procedures → inconsistencies between the different catalogs.

The AASN provide a unique opportunity to establish a consistent catalog

Diehl et al, 2009
To obtain a uniform earthquake catalogue with a target magnitude of completeness of $M \sim 2.5$.

The catalog has two main goals:

1) calculation of consistent and precise hypocenter locations

2) provide uniform magnitude calculations across the region.
Data collected

Years of continuous data: 2016, 2017, 2018

~1000 stations

HH? BH? EH? HN?
Challenges

- More than 1000 stations
- Majority of the stations are not routinely picked
- Network heterogeneity
- Large amount of data (> 30Tb)
- Consistent automatic phase picking and identification across station array
- Establish velocity models for high-precision hypocenter locations
Data quality

Vertical channel - AlpArray permanent stations

Vertical channel - AlpArray temporary stations

PERMANENT

TEMPORARY
Data completeness

before 01/01/2017 (HZ)

- AlpArray stations with majority of HHZ data
- AlpArray stations with majority of BHZ data
- Station not yet installed
- Ocean Bottom Seismometer not yet installed
Workflow

Picking detection (SC3)
- ~1000 stations (Channel: HH, BH, EH, HN)
  1. Continuous primary picking (Baer picker around trigger STA/LTA)
  2. Event declared if triggered by >15 stations

Initial automatic event catalog (SC3)
- Event location -- NonLinLoc in EDT mode -- and location quality
- Event score to select the 'best' automatic origin for each event
- Magnitude: Mlv (measured on the vertical component)

Reference picks dataset
- Creation of the reference manual picks (30 selected events)
- Quality check of magnitude estimates (find problem with metadata)

Event waveform archive
- Extraction of waveform

Tuning AutoPSy automatic picker
- Tuning of the automatic DK (Baer and Kräpfler, 1987) picker with the reference picks (P and S) and phase recognition
- Picker performance assessment, phases identification

Run AutoPSy picker in production mode
- Automatic P1-picks for all events in the automatic catalog (all waveforms in the event waveform archive), automatic S1-picks

Event locations with NonLinLoc based on refined auto-picks with 1D model for Dietl et al. (2008)

Minimum 1D model (VELEST, Kissling et al., 1998)
- Solving the coupled hypocenter-velocity problem
- Detect possible mis-picks metadata/timing errors
- Station correction for AlpArray network
- Minimum 1D model for sub-regions

Automatic refined picks (MPX, Aldersons 2004)
- Tuning of the MPX using the reference-picks dataset
- Consistent and reliable automatic first arrival P-picks together with pick-quality estimate

Event locations with NonLinLoc

Downstream products
- Magnitude
- Moment tensor
- 3D Tomo etc..
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- etc.

Workflow

Picking detection (SC3)
- ~1000 stations (Channel: HH, BH, EH, HN)
  1. Continuous primary picking (Baer picker around trigger STA/LTA)
  2. Event declared if triggered by > 6 stations

Initial automatic event catalog (SC3)
- Event location -- NonLinLoc in EDT mode -- and location quality
- Event score to select the 'best' automatic origin for each event
- Magnitude: Mlv (measured on the vertical component)
SeisComP3 (SC3) and the automatic event catalog

We configured a dedicated SeisComp3 to detect all events using an STA/LTA based detector.
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We configured a dedicated SeisComp3 to detect all events using an STA/LTA based detector.

- Separate the picking (scautopick) from the detection to allow parallel picking.
- Picks from all stations are streamed to scautoloc and scevent in playback mode. → Reduction of the playback time and processing ~1000 stations simultaneously (1 month of catalog in ~ 12 hours).
- Event score as function of distribution of residuals, gap, minimum distance, and number of observation → select the ”best” origin for each event
- 1 month of data processed in ~12 h.
- Location scheme: NonLinLoc in EDT mode using 1D alpine model (Diehl et al., 2009)
Example of SeisComP3 (SC3) tuning

- **Triggers** △ False trigger △ No trigger
- *scautoloc* internal candidate locations

**Relax conditioning:**
\[ d_x^{\text{req}} > d_{x-1}^{\text{req}} \]

**Legend:**
- Red triangles: Triggers
- Yellow triangles: False triggers
- White triangles: No triggers
- Green stars: *scautoloc* internal candidate locations

**Diagram:**
- Longitude vs. Latitude
- Required distance to 4th station \( d_4^{\text{req}} \)

[Graph showing the relationship between travel time and distance, with conditions for selecting triggers.]
SC3 catalog vs ISC catalog (2016)

**SC3 catalog** = 127
(event score > -1, M > 2.2)
Paired = 91
Not paired

**ISC bulletin** = 112
(M >= 2.4)
Paired = 91
Not paired

Tuning of SC3 needed
Doubt event (not existing or very small)

First 6 month of 2016, M > 2.4
**Workflow**

**Picking detection (SC3)**
- ~1000 stations (Channel: HH, BH, EH, HN)
  1. Continuous primary picking (Baer picker around trigger STA/LTA)
  2. Event declared if triggered by > 15 stations

**Initial automatic event catalog (SC3)**
- Event location -- *NonLinLoc* in EDT mode -- and location quality
- Event score to select the 'best' automatic origin for each event
- Magnitude: Mw (measured on the vertical component)

**Reference picks dataset**
- Creation of the reference manual picks (30 selected events)
- Quality check of magnitude estimates (find problem with metadata)

**Event waveform archive**
- Extraction of waveform

**Tuning AutoPSy automatic picker**
- Tuning of the automatic BK (Baer and Krämer, 1987) picker with the reference picks (P and S) and phase recognition
- Picker performance assessment, phases identification

**Run AutoPSy picker in production mode**
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**Event locations with *NonLinLoc***

**Downstream products**
- Magnitude
- Moment tensor
- 3D Tomo
- etc..
Reference Dataset
Workflow

Initial automatic event catalog (SC3)
- Event location -- **NonLinLoc** in EDT mode -- and location quality
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- etc.
AutoPSy auto picker

KP201604071825 - BERNI - CH - 253.96 km

M. Bagagli
AutoPSy auto picker

SD: 0.55
MEAN: -0.2

M. Bagagli
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Event locations with nonLinLoc

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Discussion

- Assess the quality class for each pick.
- Minimum 1D model for the entire region and for specified sub-regions
- Implementation of an automatic phase detection algorithm
- Magnitude relation and magnitude calculation

The catalog could be the starting point to investigate lower magnitude seismicity in key regions using template matching algorithms.

Collaboration with Z. Ross and M-A Meier from Caltech
Example of SeisComP3 (SC3) tuning