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SeisComP3 iLoc Integration Applied to Array Processing

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Summary

With the recent SeisComP3 release iLoc is provided as a new locator for seismic and infrasound events. It extends the already available seismic event locators LocSat, Hypo71 and NonLinLoc. iLoc is the extension of the standard ISC locator algorithm optimized for seismic event monitoring by local and regional networks, NDCs and global event location studies. With iLoc the open source SeisComP3 system is also able to integrate results from array processing modules like GEMPA's commercial software package LAMBDA. To support array processing the graphical user interfaces of the open source SeisComP3 package have been extended to consider phase picks for event localization with slowness and backazimuth in addition to the detection time.

Therefore iLoc as a native SeisComP3 locator allows to use the full capacity of array processing in LAMBDA and SeisComP3 during real-time automatic and interactive analysis. LAMBDA provides several array processing techniques as static and dynamic F-K analysis, beam packing and backprojection along traveltime curves. As infrasound phases are supported by iLoc, the seismic and infrasound phases derived by LAMBDA can be used within the localization.

Here we present the array processing results for the nuclear weapons tests of North Korea and other induced seismic events applying the iLoc implementation compared to the existing locators like LocSat.

iLoc – The New Earthquake Locator in SeisComP3

iLoc history

- Originally developed for U.S. Air Force Research Laboratory, today the standard at the International Seismological Centre (ISC) replacing previous routines
- OpenSource: https://seiscode.iris.washington.edu/projects/iloc
- **Integrated in SeisComP3 in 2019**

iLoc in a nutshell

- Accounts for correlated travel-time prediction errors
- Initial hypocenter guess from Neighbourhood Algorithm search
- Linearised inversion using a priori estimate of the full data covariance matrix
- Attempts for free-depth solution only if there is depth resolution
- Default depth is derived from historical seismicity
- Seismic, hydroacoustic and infrasound observations
- Arrival time, slowness and azimuth measurements
- Uses most ak135 or iasp91 Earth model phases in locating
- Integrated RSTT travel-time predictions
- RSTT is default for Pn/Sn and Pg/Lg
- Local velocity model and local phase TT predictions for Pg/Sg/Lg, Pb/Sb, Pn/Sn

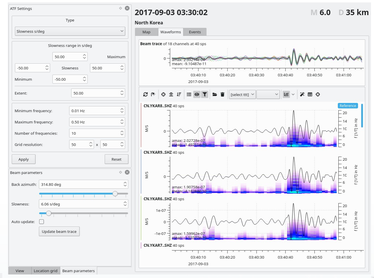
iLoc adaptations and integration into SeisComp3

- Successful integration by providing a library of routines
- SeisComP3 calls iLoc routines by passing the objects
- iLoc returns objects to SeisComP3 for integration
- SeisComP3: graphical interface for configuration
- iLoc implementation retains all original iLoc functionalities

LAMBDA – The New Seismic and Infrasound Array Module for SeisComP3

LAMBDA for SeisComP3

LAMBDA is gempa's advanced seismic **array processing** package for detecting and locating **seismic or infrasound events** outside of network coverage. It provides manual phase identification with plane-wave fitting and automatic F-K analysis or beampacking to identify the onset time, slowness and backazimuth of P and other phases.

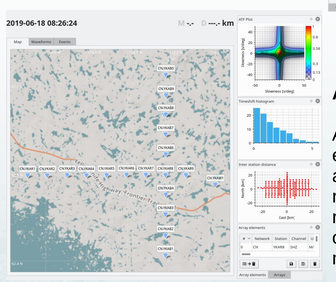


Interactive beamforming (left)

Beams can be formed on the fly to visualize phases and to estimate array parameters.

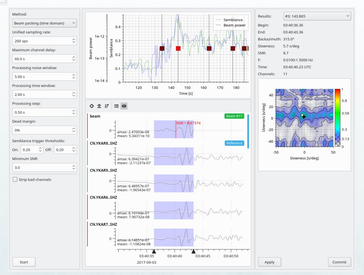
Interactive F-K analysis (below)

Searching the data for the most likely beam detections is assisted by interactive setting of time windows, thresholds, etc.



Array design (left)

Arrays can be formed interactively from existing stations on a map or from a table and saved for later application. The array response for a configurable frequency range, time shift histograms and diagrams of inter-station distances provide valuable measures of the array design.



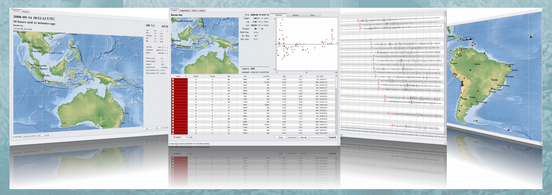
SeisComP3 – Real-Time Event Monitoring

Professional earthquake and explosion monitoring

- Automatic detection in real time
- Earthquake and explosions at local – teleseismic distances
- Full magnitude range: micro – mega earthquakes
- Open source: https://github.com/SeisComP3/seiscomp3

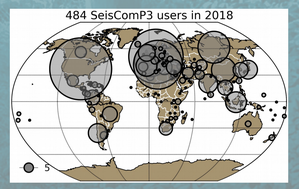
User friendly analysis in real time and post processing

- Picks, locations, magnitudes
- Event classification
- Focal mechanisms



World-wide application

- Professional researchers, earthquake and nuclear monitoring experts: IDC, NDCs
- Recommended and distributed by CTBTO: ENIAB VM
- Software trainings provided at CTBTO by gempa GmbH

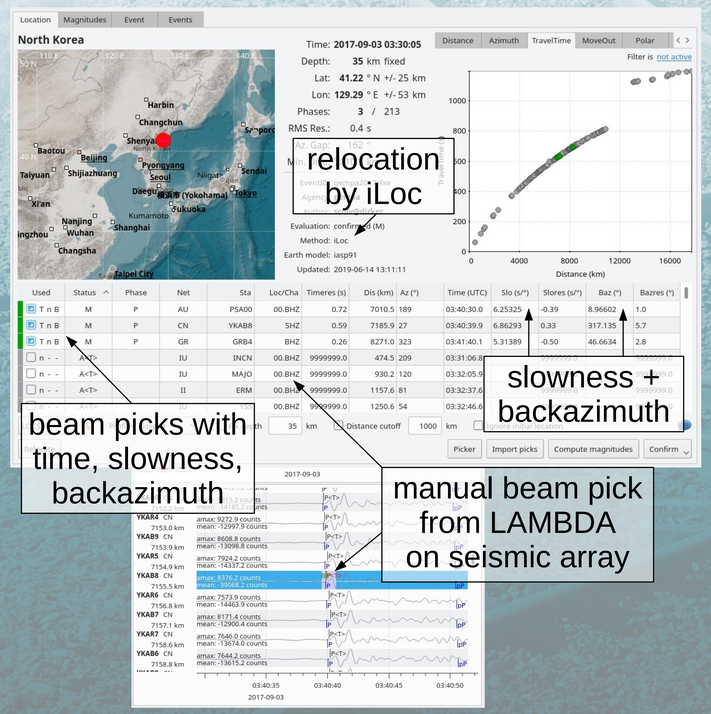


References

Iloc: Bondár, I., and D. Storchak, Improved location procedures at the International Seismological Centre, Geophys. J. Int., 186, 1220-1244, doi:10.1111/j.1365-246X.2011.05107.x, 2011.

Array Applications – Nuclear Tests in North Korea: 06/01/2016, 09/09/2016, 03/09/2019

Interactive SeisComP3 analysis by scolv and iLoc: processing beam picks is now fully integrated



The beam parameters, pick time and backazimuth, from P phases at **3 arrays** (Gräfenberg, Yellowknife, Palm Springs) were determined using LAMBDA. They allow to locate the Nuclear Explosions in N Korea accurately. Without any further processing such as manual re-picking, **the standard automatic event solutions are within 5 km of the solutions provided by USGS and GEOFON.**

The **array locations are nearby** without any empirical corrections.

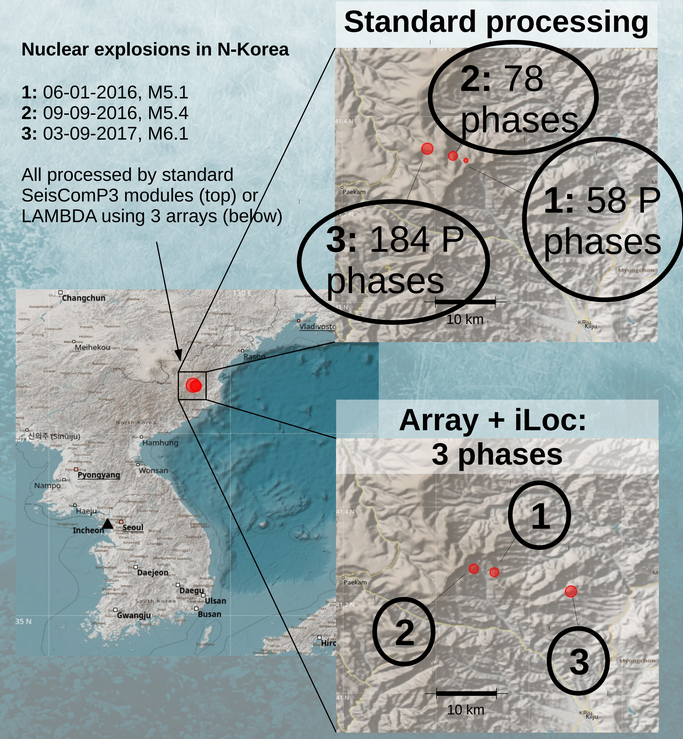
The picks and the locations from LAMBDA can be used further by public SeisComP3 or gempa modules such as scanloc.

In this study the beam picks from the 3 arrays were combined to locate the event. In other cases, combining the beam detections from one array with just very few more stations results in reliable locations and which can be further analyzed interactively and relocated by iLoc in scolv.

Nuclear explosions in N-Korea

1: 06-01-2016, M5.1
2: 09-09-2016, M5.4
3: 03-09-2017, M6.1

All processed by standard SeisComP3 modules (top) or LAMBDA using 3 arrays (below)



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

PUTTING AN END TO NUCLEAR EXPLOSIONS