Realtime detection and location of very local seismicity using SeisComp3

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PETROBRAS fund this work through an ANP project.

#EGU20

Abstract Id: EGU2020-3912

MOTIVATION

SeisComp3 (SC3) is a standard tool to detect and locate teleseismic events. It has tools to receive, detect, locate, review and disseminate information with a set of GUIs and well-established protocols such as SeedLink and FDSN Web-Services. Also, it stores data in standard MSEED format files, organized in a folder tree named SDS (*SeisComp3 Data Structure*). On the other hand, it is all tuned to handle stations from dozens of kilometers to hundreds of degrees.

We used it in this project to handle a network with up to 712 stations, 4 channels, in only ~9 km² (Figure 1). Each channel is a time series with 500 sps and has arbitrary orientations along the network. So far, we focused on analyzing a 7 hours time window where ~1000 events were expected.

Initial results show the benefit of working inside SeisComp3 infrastructure, but tools need to be tuned in source code to function correctly. SeisComp3 performance of handling the data volume is outstanding.

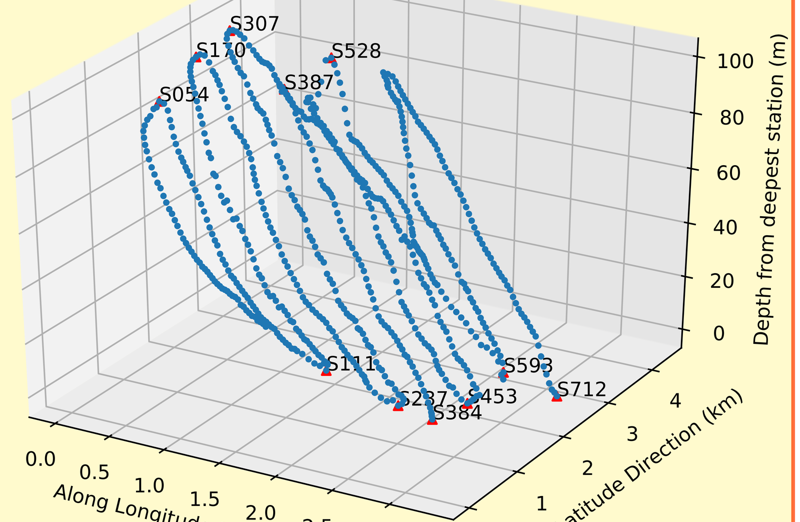


Fig. 1: Station Locations

EVENTS

- Events are tiny and many occur within seconds apart. Fig. 2 show two earthquakes recorded at station S233. Complete waveform, with P, S, and possible Surface waves, have less than 5 seconds.
- On pressure sensors (DDH) PwP phases, the water multiples, are visible, stations are located > 1000 m depth.
- Beyond this multiple, still strong conversion from the sediments, like the Ps and possible Sp phases, could "contaminate" events.

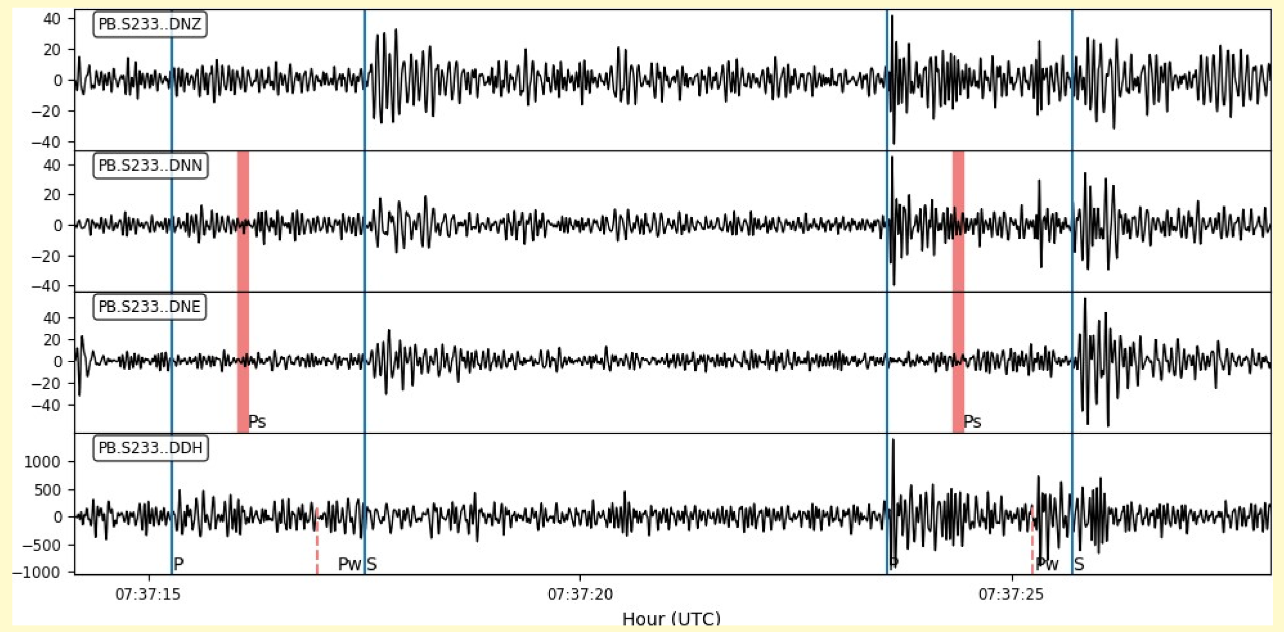


Fig. 2: Two earthquakes recorded at station S233. Blue are P and possible S phases, dashed red are clear PwP multiple and red shadow region for Ps sediment multiple.

RESULTS DISCUSSION

- Compared Different detection catalogs:
  - STA/LTA DNE (Green), STA/LTA DDH (Red), Template Correlation (Blue), Initial Catalog (Purple);
- Different template results concentration may indicate slightly different locations or focal-mechanisms;
- Unity integral normalized histograms have a similar shape, indicating that there is a consistent increase in numbers of events around 07:20, 07:35, and 08:00. The largest event occurred at 07:59, and a clear decrease of density is observed related to this energy release, followed by sporadic, but consistent detection;
- Depths were estimated, but is confidential to project members.

METADATA PREPARATION

NetTab Files

- Flat text files that can describe all the XML entries in inventory;
- Easy to handle restrictions;
- Vi-Editable;

Nettab

```
01: Dl: DTA0 1.0 10000.0 0.0 none 10,100,250,500
02: Se: SEN0 1.0 1.0 1.0 1.0 0 0
03:
04: Nw: PB XXXX*/001
05: Na: Description="Petrobras, Network, Brasil"
06:
07: Sa: Restricted=True *,*,*,*
08:
09: Sl: S001 "Station 001" DTA0 SEN0 TN_D500 ZNE \
    -XX.XXX* -XX.XXX* -XXX.X* 0.0 XXXX*/001
10: Sl: S001 "Station 001" DTA0 SEN0 TD_D500 H(0.0,0.0) \
    -XX.XXX* -XX.XXX* -XXX.X* 0.0 XXXX*/001
11: …
```

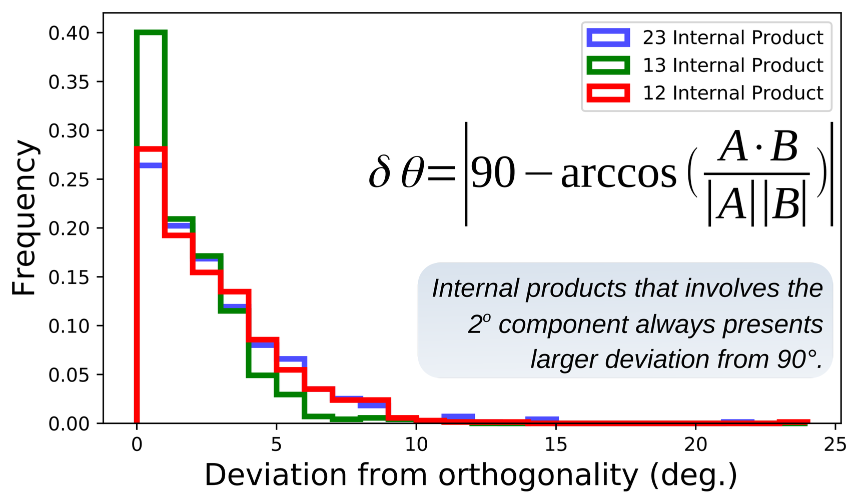
Gain = 1 / Network / Station

NetTab v.2 Format:https://www.seiscomp3.org/doc/special/nettabv2.html
** Year, Latitude, Longitude and Depth are restricted for this data processed.*

- **SC3 has internal tools to convert nettab directly to XML inventory**

```
% seiscomp exec tab2inv -g <TabFilename> \
        > ~/seiscomp3/etc/inventory/zne.xml
```

- **Inspected channel metadata are not 100% orthogonal – energy leakage during rotation.**



BUILDING SDS *and* SEEDLINK INJECTION

Data Conversion

- SEGy → MSEED using *iread_segy* from *Obspy*
- Data was in chunks of 30 seconds, process: Read, Rotate, Fix Headers and Inject to a FIFO in SeedLink, or pass to SC3 scart.

- **A_n and D_n are the Azimuth and Dip angles for channels n = 1,2,3. U_n represents RAW data.**
- **The pressure component has no orientation.**

Rotation Matrix

$$\begin{bmatrix} z \\ n \\ e \end{bmatrix} = \begin{bmatrix} sin(D_1) & sin(D_2) & sin(D_3) \\ cos(D_1)cos(A_1) & cos(D_2)cos(A_2) & cos(D_3)cos(A_3) \\ cos(D_1)sin(A_1) & cos(D_2)sin(A_2) & cos(D_3)sin(A_3) \end{bmatrix} * \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix}$$

BUILDING a SDS

- SDS can be built using SC3 tool ***scart***

SEEDLINK INJECTION

- Seedlink can read from a FIFO, that can be created using ***mkfifo*** comand.

```
– seedlink.cfg begin
# Path to named fifo pipe
plugins.mseedfifo.fifo = /home/realtime/\
          seiscomp3/var/run/seedlink/mseedfifo

# Do not exit plugin if writer closes the fifo.
plugins.mseedfifo.noexit = true
–
```

- Station acquired by the FIFO should have a profile defined as:

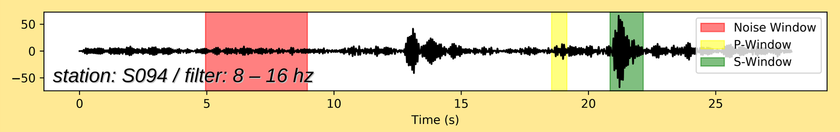
```
– seedlink/profile_FIFO
# Activated plugins for category sources
sources = FIFO:mseedfifo
–
```

BUG: SeedLink FIFO plugin template has a bug, that should be manually fixed so that it can stay UP after all connections are closed, and of course, start normally.

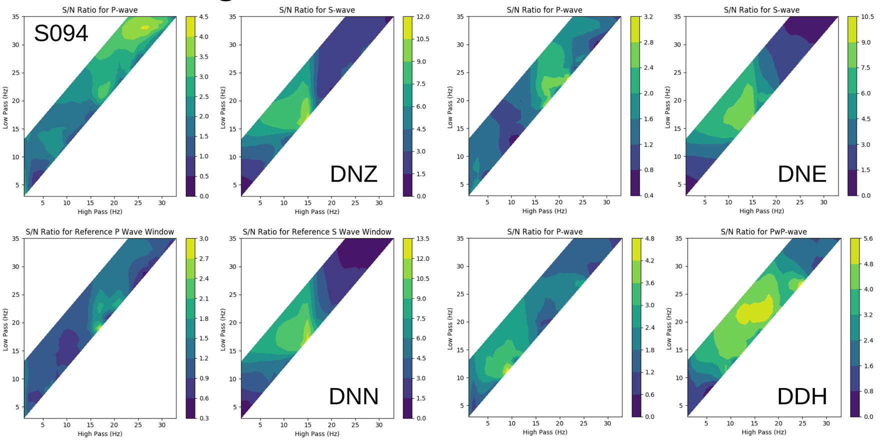
DETECTION

Filter Optimization

- We choose the filter by maximizing the SNR of a phase window (yellow or gree) vs. a Noise (red) Window, manually selected before P-wave.
- All filters combinations from 1 to 35 hz w/ a min bandwidth = 2 Hz and max bandwidth = 6 Hz



S094: Signal to Noise Ratio



SCAUTOPICK

- Is SC3 STA/LTA detector & picker – we just did detection – no pick refinements (yet!)
- 2 filter corners + 4 *scautopick* parameters: (a) STA window, (b) LTA window, (c) Trigger On and (d) Trigger Off values → **GOES TO SC3 BINDING!**

	HP	LP	STA	LTA	T.On	T.Off
DNE	*8 Hz*	*15 Hz*	*0.2 s*	*10 s*	*2.5*	*1.0*
DDH	*13 Hz*	*17 Hz*	*0.3 s*	*10 s*	*1.8*	*1.0*

- We target S-wave only
  - Replaced the P-wave travel time table by S-wave table
  - Pick S-wave as P-wave
- Scautopick command line (*run in parallel*):

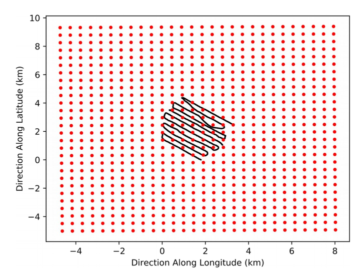
```
% scautopick --playback --offline -I $F \
   -d $DB --ep --trigger-dead-time 2.0 \
   --amplitudes 0
```

$DB is database connection / *$F is inventory* / *Adjust to your needs*

NUCLEATION *and* LOCATION

SCAUTOLOC

- Is the SC3 automatic locator responsible for nucleating new Origins.
- Needed source code changes:
  - Disable regional equations of weighting;
  - Set internal MaxUsedRMS and GoodRMS values;
  - Increase Nucleation number to 20 instead of 6;
  - Increase pick affinity to 0.2 instead of 0.05 to be valid;
  - Reduce outlier limit of 3σ to 1.5σ
- Used a modified nucleation Grid & Traveltime Tables

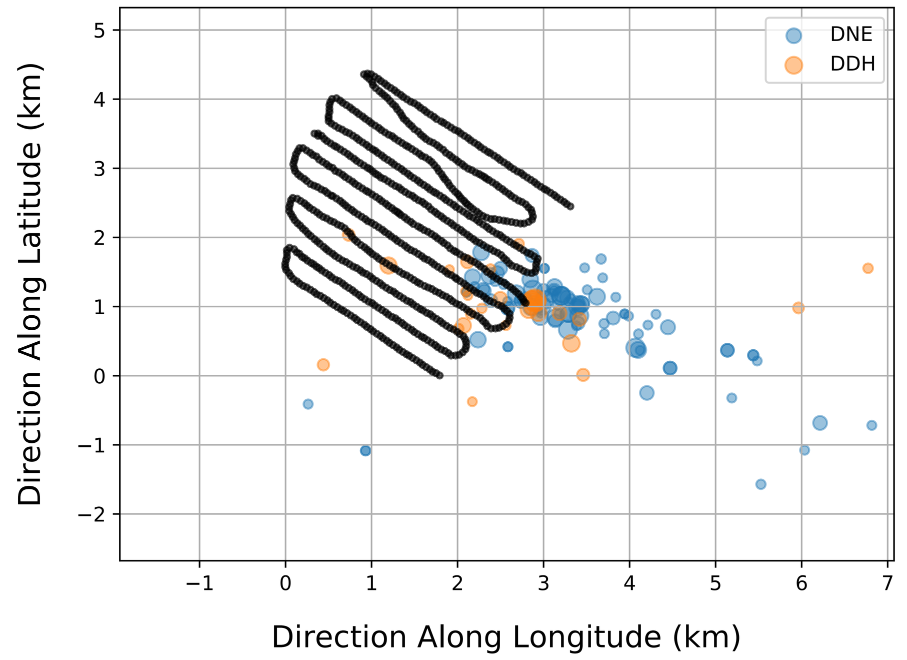


- For offline playback, picks were split by time in different files and, many copies of scautoloc were executed in parallel
- Later origins were collected back to a single SC3-XML file.

Results

- 106 (96 in map) events(*) detected by DNE.
- 35 (33 in map) events(*) detected by DDH.

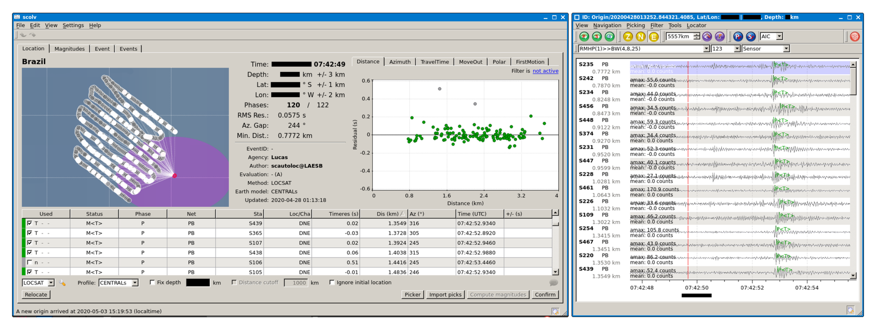
(*) Origins w/ < 4 s time difference



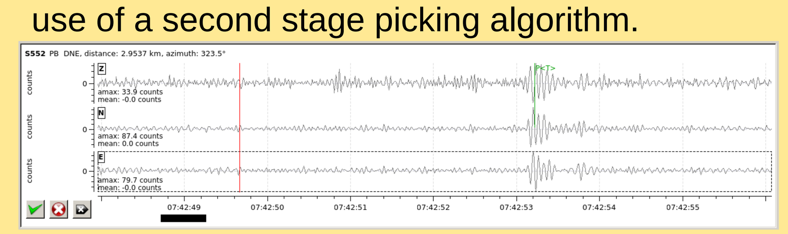
REVISION

SCOLV

- Is the traditional SC3 review tool
  - Offline reviewing and relocating the events
  - Adjustment to the residual widget source code allowed to zoom into the residuals, just setting it to km was not enough.



- Fully automatic event w/ > 120 readings;
- Good residual structure, picked on S-wave;
- Lots of pick improvements are still possible by the use of a second stage picking algorithm.



TO BE DONE ...

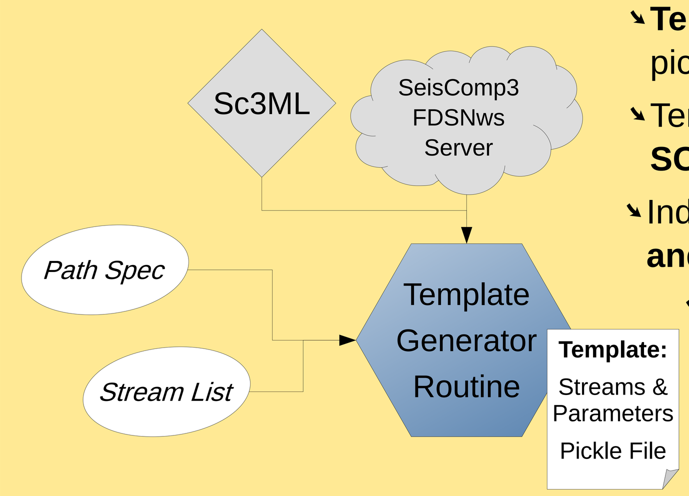
- While we were able to acquire the full network in SC3 simulation, all STA/LTA detections used 250 stations and, template detection used just 150. **Need to increase these values**.

- SC3 *scevent* tool still cannot handle the fine grainy of the origins detected, when it receives the current origins, it tends to group origins from different events together.

- Lots of code clean-up and organization.
- Better documentation.
- Integrate NLL locator using the *screloc* tool in the pipeline to generate a final catalog.

- Finish integrating a Template search package implemented in Python, using EQCorrScan into the full pipeline as an alternative to STA/LTA detection method.

TEMPLATE SEARCH (EqCorrScan)



- **Templates are**: Manual picked and located events
- Template **creation based** on **SC3ML and FDSNws** servers
- Individual templates from **P and S-wave were merged**
- Matched against continuous records to detect events above a minimum threshold
- **We tested so far with a total of 6 templates. Results are presented in the results discussion.**