SnT 2019

CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Ivan Kitov[1], Mikhail Rozhkov[1], Maxim Kokoulin[2]

1 - Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization

2 - Instrumental Software Technologies, Inc.

# Continuous assessing of the Reviewed Event Bulletin with waveform cross correlation

# Outline

- Spot Check Highlights
- Selection of Master Events
- Automatic Spot Check
- Interactive Spot Check
- Spot Check Tool Architecture
- Discussion

# Spot Check Highlights

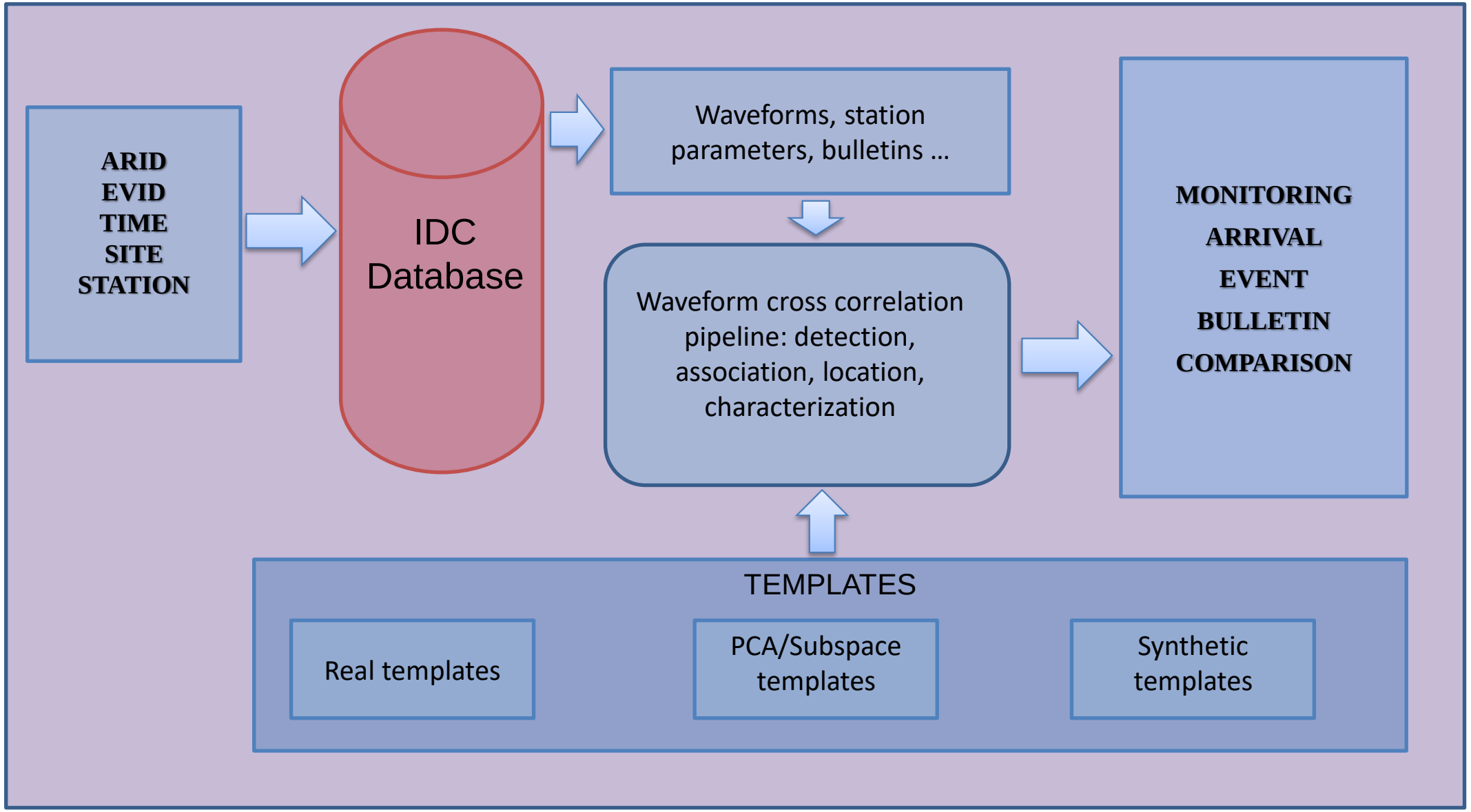
- Aimed at improvement of the Reviewed Event Bulletin (REB) quality
- Final level of the interactive review hierarchy (independent review)
- Provides an extended check of bulletin and the analysis quality
- Identifying both consistencies and inconsistencies in the REB
- Reviewed areas usually include event location anomalies, seriously mislocated events, missing large events, and unqualified or ‘bogus’ events representing incorrect / invalid data associations or incorrect detections, or REB events not meeting IDC event definition criteria, EDC
- One more implementation of the master-event approach
- Teleseismic and regional, natural and man-made sources, seismic and infrasound technologies.

# *Spot Check Tool* is the *Spot Check* Implementation at the IDC

- *SCT development started as the CC-based techniques are in use for many years at the IDC.*
- *SCT development*: to facilitate a work of the Independent Reviewer (IR)
- *Underlying methodology*: waveform cross correlation involving master-event approach
- *Modes*: Interactive and Automatic
  - Interactive: under flexible scenario developed by the IR
  - Automatic: on daily basis, building XSEL (cross correlation standard event list) and conducting automatic comparison with SELs (same day analysis) and REB (upon its completion) bulletins. *Inherits functionality of the Spot Check Prototype.*

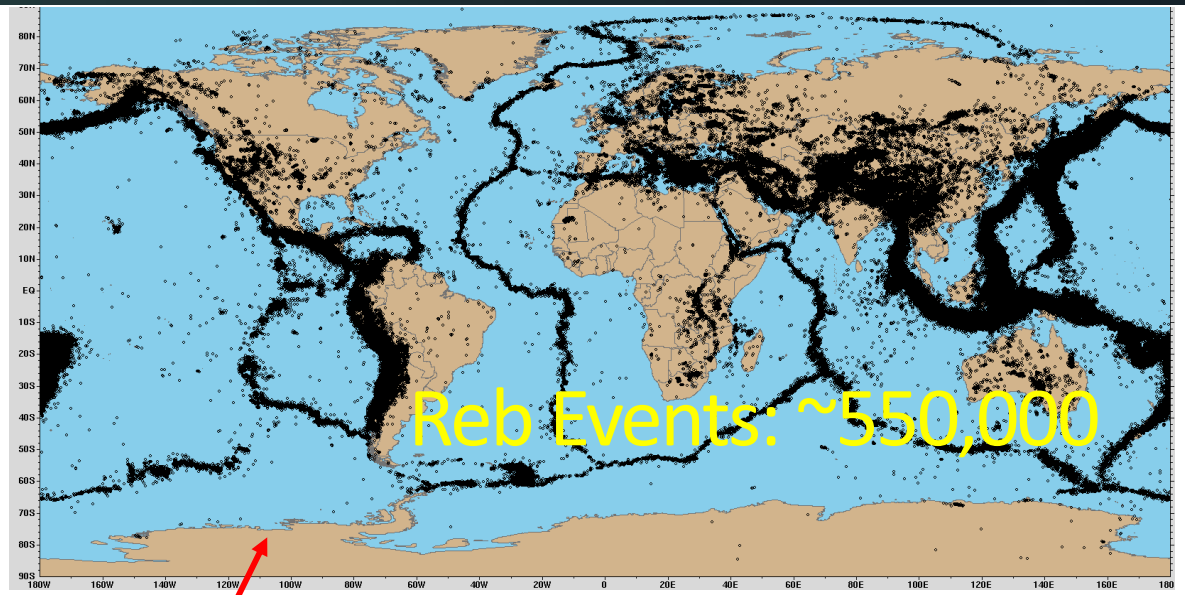
# Spot Check Tool Background

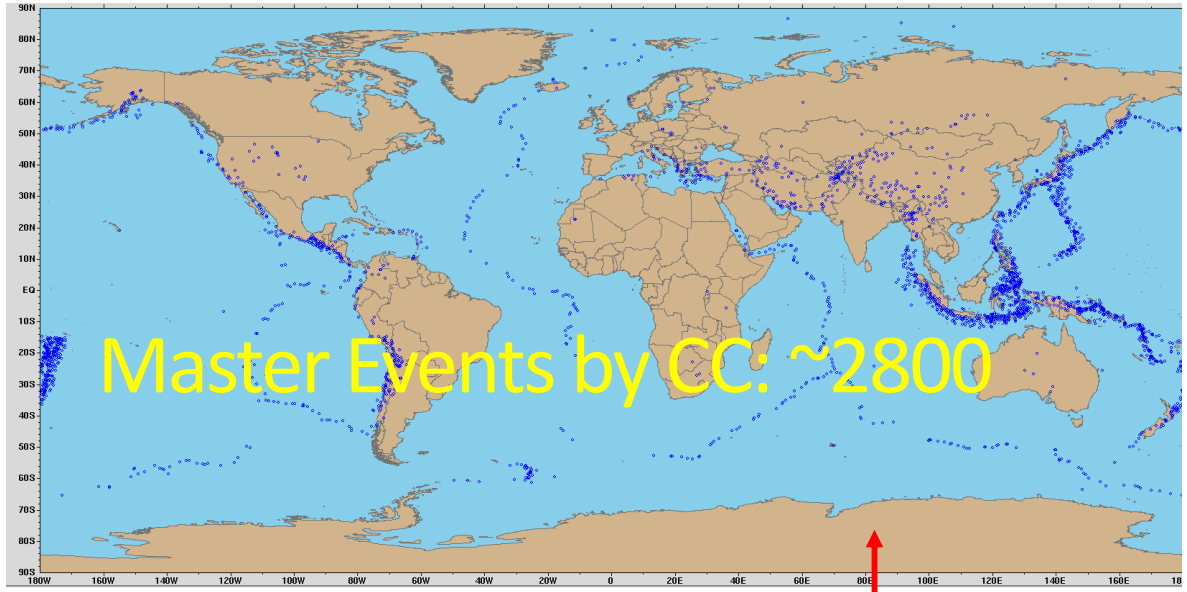
## Generalized Spot Check Diagram



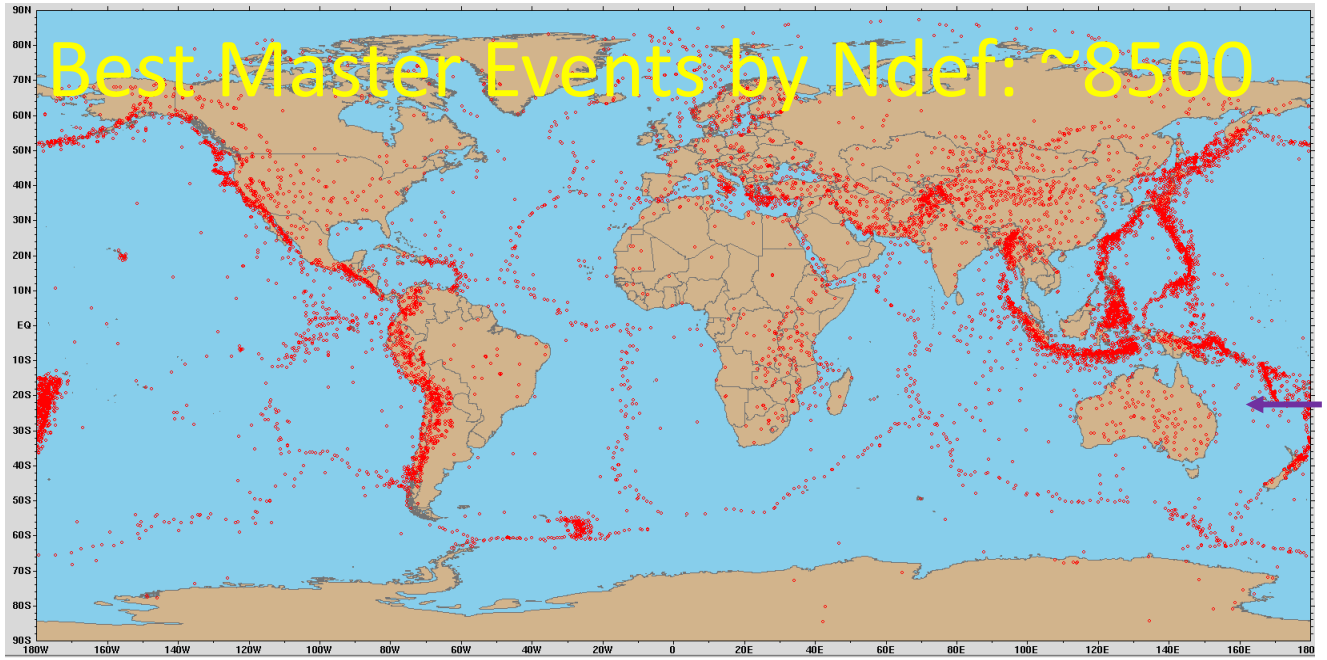
# Spot Check Tool Background
## Master Event Selection






There are currently >550,000 REB events with two or more primary seismic stations. All these events can be used as master events in waveform cross correlation. More than 100 new REB events are added every day.



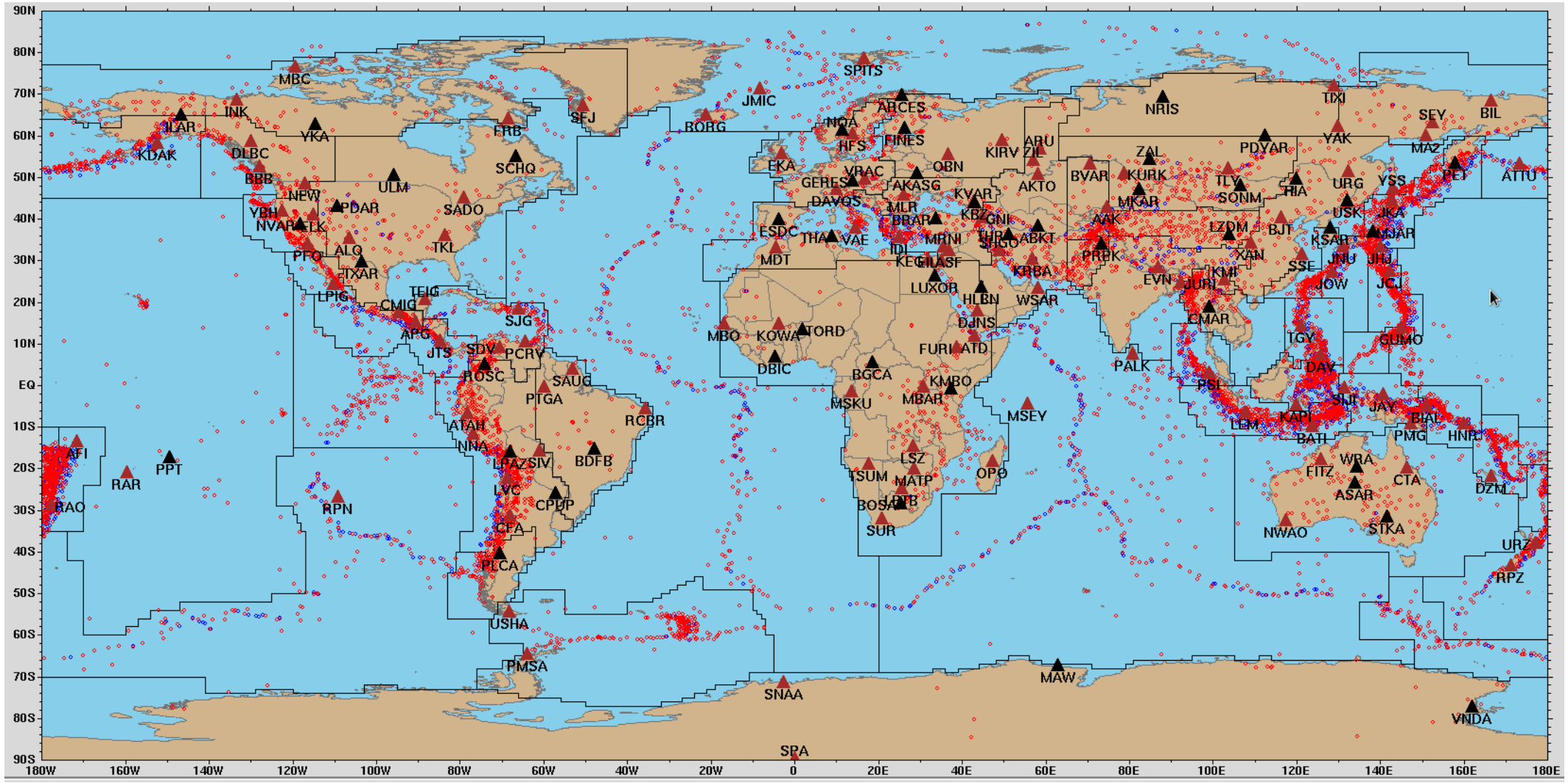

All REB events in each 1x1 degree cell are cross correlated to select one most efficient master event in the cell. At least 40 REB events have to be within each cell. Depth cells: 40 km thick from 0 to 700.

For the globe divided into 1x1 degree cells, we select one REB event (mb<5) by NDEF as a representative master event in each cell if available. Depth cells: 40 km thick from 0 to 700.

# Spot Check Tool Background

## Station Input Depends On Seismic Region






Division of ME by seismic regions expresses predominant tectonic regime and geology, i.e. source mechanisms of seismic events and propagation characteristics. Such ME are likely representative, and thus, more efficient in SCT search.

# Spot Check Tool Background

## Station Input Depends On Seismic Region



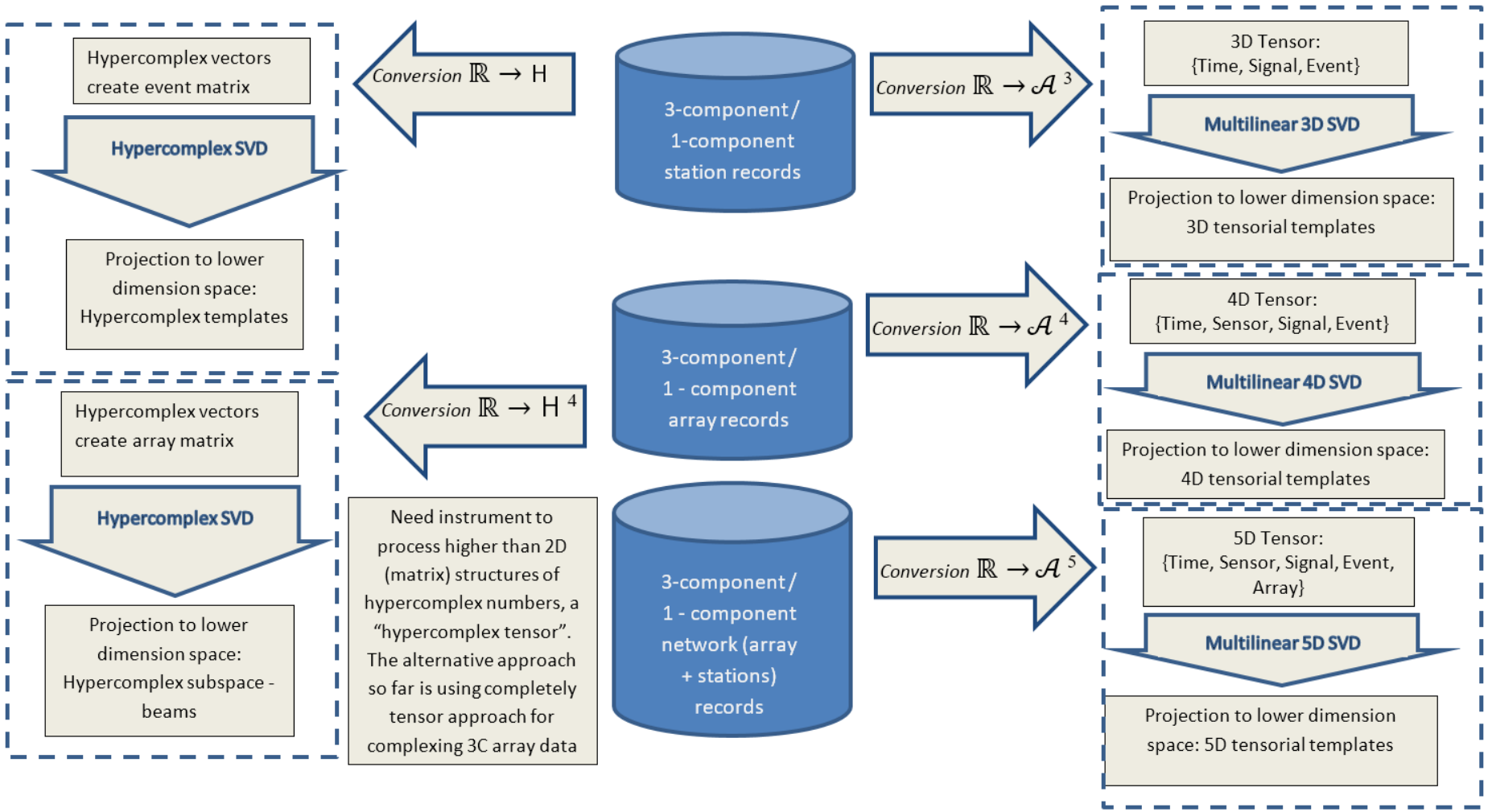
### Participation rate of primary seismic stations in REB events in 50 Flinn-Engdahl seismic regions

| Seis_Reg | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AKASG | 0.15 | 0.12 | 0.06 | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.05 | 0.17 | 0.01 | 0 | 0 | 0 | 0.03 | 0.14 | 0.15 | 0.03 | 0.03 | 0 | 0 | 0.08 | 0.06 | 0.04 | 0 | 0.47 | 0.41 | 0.18 | 0.44 | 0.1 | 0.02 | 0 | 0.35 | 0.14 | 0 | 0.05 | 0.31 | 0.09 | 0.18 | 0.03 | 0.01 | 0.06 | 0.02 | 0.11 | 0.08 | 0.25 | 0.14 |
| ARCES | 0.13 | 0.02 | 0.01 | 0.02 | 0.14 | 0.03 | 0.08 | 0 | 0 | 0.13 | 0.17 | 0.08 | 0.09 | 0.29 | 0 | 0 | 0.14 | 0.12 | 0.05 | 0.03 | 0.04 | 0.16 | 0.02 | 0.01 | 0.15 | 0.32 | 0.26 | 0.02 | 0.22 | 0.27 | 0.18 | 0.08 | 0.02 | 0.14 | 0.06 | 0.88 | 0.06 | 0 | 0 | 0.71 | 0.08 | 0.11 | 0.01 | 0.01 | 0 | 0.17 | 0.52 | 0.57 | 1.11 | 0 |
| ASAR | 0.19 | 0 | 0.01 | 0.03 | 0.11 | 0.33 | 0.04 | 0.17 | 0 | 0.26 | 0.99 | 0.99 | 0.99 | 0.97 | 0.97 | 0.99 | 0.82 | 0.77 | 0.46 | 0.69 | 0.83 | 0.96 | 0.98 | 0.98 | 0.8 | 0.67 | 0.35 | 0.03 | 0.05 | 0.02 | 0.02 | 0.11 | 0.94 | 0 | 0.19 | 0 | 0.05 | 1.14 | 0.79 | 0.07 | 0.41 | 0.08 | 0.56 | 0.06 | 0.99 | 0.8 | 0.44 | 0.24 | 0 | 1 |
| BDFB | 0 | 0 | 0 | 0.01 | 0.07 | 0.06 | 0.03 | 0.39 | 0.32 | 0.07 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.11 | 0 | 0 | 1 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0 |
| BOSA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.08 | 0.29 | 0.15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0 | 0 | 0.01 | 0.01 | 0.01 | 0.11 | 0.12 | 0 | 0.06 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.06 | 0.02 | 0 | 0 | 0 | 0.14 |
| BRTR | 0.03 | 0.03 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0.05 | 0 | 0.02 | 0.01 | 0.09 | 0 | 0 | 0 | 0 | 0.03 | 0.02 | 0.14 | 0.08 | 0.03 | 0.01 | 0.02 | 0.04 | 0.02 | 0.13 | 0.01 | 0.39 | 0.77 | 0.19 | 0.37 | 0.15 | 0 | 0 | 0.02 | 0.25 | 0 | 0 | 0.18 | 0.03 | 0.04 | 0.02 | 0.07 | 0.04 | 0.12 | 0.02 | 0.07 | 0 | 0 |
| BVAR | 0.14 | 0.02 | 0.03 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0.01 | 0.02 | 0.03 | 0.02 | 0 | 0.04 | 0.11 | 0.21 | 0.15 | 0.07 | 0.12 | 0.13 | 0.09 | 0.05 | 0.04 | 0.09 | 0.13 | 0.36 | 0.17 | 0.57 | 0.03 | 0.04 | 0.04 | 0.04 | 0.01 | 0 | 0.02 | 0.04 | 0 | 0.18 | 0.08 | 0.06 | 0.04 | 0 | 0.05 | 0.01 | 0.1 | 0.42 | 0.53 | 0.03 | 0 |
| CMAR | 0.1 | 0.04 | 0 | 0.01 | 0.06 | 0.01 | 0.01 | 0 | 0 | 0.07 | 0.28 | 0.07 | 0.13 | 0.28 | 0.21 | 0.18 | 0.38 | 0.11 | 0.06 | 0.06 | 0.21 | 0.31 | 0.1 | 0.19 | 1.01 | 0.46 | 0.26 | 0.01 | 0.13 | 0.05 | 0.06 | 0.01 | 0.48 | 0 | 0 | 0 | 0.12 | 0.03 | 0.26 | 0.1 | 0.17 | 0.07 | 0.03 | 0.01 | 0.12 | 0.66 | 0.04 | 0.02 | 0 | 0 |
| CPUP | 0 | 0 | 0 | 0.03 | 0.04 | 0.01 | 0.03 | 0.33 | 0.92 | 0.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.12 | 0.02 | 0 | 0.31 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0 | 0.18 | 0.16 | 0.04 | 0 | 0 | 0 | 0 | 0 |
| DBIC | 0 | 0 | 0 | 0 | 0.01 | 0.03 | 0.2 | 0.25 | 0.09 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0.02 | 0.03 | 0.01 | 0.25 | 0.01 | 0 | 0.06 | 0 | 0.2 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FINES | 0.19 | 0.11 | 0.06 | 0.04 | 0.02 | 0.01 | 0.1 | 0 | 0 | 0.22 | 0 | 0.1 | 0.03 | 0.06 | 0 | 0 | 0.41 | 0.46 | 0.32 | 0.45 | 0.22 | 0.22 | 0.02 | 0.01 | 0.17 | 0.36 | 0.43 | 0.03 | 0.65 | 0.55 | 0.62 | 0.22 | 0.04 | 0.08 | 0 | 1.02 | 0.2 | 0.01 | 0.18 | 0.67 | 0.35 | 0.3 | 0 | 0 | 0.02 | 0.23 | 0.42 | 0.58 | 1.1 | 0 |
| GERES | 0.03 | 0.01 | 0.02 | 0 | 0.02 | 0.01 | 0.03 | 0 | 0.05 | 0 | 0 | 0 | 0.01 | 0.03 | 0.03 | 0 | 0 | 0 | 0.03 | 0.02 | 0.03 | 0 | 0 | 0 | 0.11 | 0.06 | 0.05 | 0 | 0.12 | 0.4 | 0.66 | 0.26 | 0.01 | 0 | 0.06 | 0.78 | 0.26 | 0 | 0 | 0.35 | 0.01 | 0.05 | 0.02 | 0 | 0 | 0.13 | 0.01 | 0.02 | 0.01 | 0 | 0 |
| GEYT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0 | 0 | 0 | 0.03 | 0.01 | 0 | 0.01 | 0.03 | 0.03 | 0.06 | 0 | 0.45 | 0.05 | 0.02 | 0.01 | 0.03 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.02 | 0.01 | 0.01 | 0 | 0.01 | 0 | 0.09 | 0.29 | 0.44 | 0 | 0 |
| ILAR | 0.93 | 0.82 | 0.57 | 0.72 | 0.76 | 0.55 | 0.34 | 0.03 | 0.12 | 0.02 | 0.02 | 0.19 | 0.51 | 0.53 | 0.52 | 0.41 | 0.69 | 0.39 | 0.43 | 0.22 | 0.15 | 0.17 | 0.04 | 0.01 | 0.08 | 0.11 | 0.17 | 0.03 | 0.06 | 0.02 | 0.05 | 0.33 | 0.03 | 0.27 | 0.13 | 0.01 | 0.02 | 0 | 0.67 | 0.54 | 0.38 | 0.98 | 0.25 | 0.85 | 0.17 | 0.01 | 0.03 | 0.09 | 0.01 | 0 |
| KBZ | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.02 | 0.04 | 0.02 | 0 | 0 | 0.01 | 0 | 0 | 0.01 | 0 | 0.3 | 0.18 | 0.12 | 0.05 | 0.02 | 0 | 0 | 0.01 | 0.02 | 0 | 0.02 | 0.05 | 0 | 0 | 0 | 0.01 | 0.02 | 0 | 0.04 | 0.02 | 0 | 0 |
| KEST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0.05 | 0.43 | 0.07 | 0 | 0 | 0 | 0.02 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0 |
| KMBO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0.21 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| KSRS | 0.06 | 0.01 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0.13 | 0.04 | 0.01 | 0.03 | 0.06 | 0.06 | 0.08 | 0.23 | 0.18 | 0.68 | 0.55 | 0.13 | 0.07 | 0.06 | 0.01 | 0.11 | 0.09 | 0 | 0.05 | 0.02 | 0.01 | 0 | 0.03 | 0 | 0 | 0 | 0 | 0.02 | 0.12 | 0 | 0.68 | 0.01 | 0.01 | 0 | 0 | 0.1 | 0.03 | 0 | 0 | 0 |
| KURK | 0.16 | 0.07 | 0.07 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.01 | 0.08 | 0.04 | 0 | 0 | 0.05 | 0.09 | 0.26 | 0.25 | 0.27 | 0.27 | 0.32 | 0.29 | 0.21 | 0.13 | 0.37 | 0.66 | 0.59 | 0.94 | 0.54 | 0.24 | 0.1 | 0.1 | 0.12 | 0 | 0 | 0.02 | 0.13 | 0.02 | 0.26 | 0.19 | 0.25 | 0.13 | 0.02 | 0.05 | 0.01 | 0.29 | 0.64 | 0.66 | 0.03 | 0 |
| LPAZ | 0 | 0 | 0.04 | 0.01 | 0.12 | 0.08 | 0.16 | 0.78 | 0.51 | 0.75 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.24 | 0 | 0.01 | 0.44 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0.44 | 0.34 | 0.08 | 0 | 0 | 0 | 0.14 |
| MAW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | 0.06 | 0.21 | 0.04 | 0.05 | 0.02 | 0.05 | 0.02 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0.08 | 0 | 0 | 0 | 0.02 | 0.01 | 0.02 | 0 | 0 | 0 | 0.06 | 0 | 0.09 | 0 | 0 | 0 | 0 | 0.43 |
| MJAR | 0.02 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.04 | 0.07 | 0.05 | 0.02 | 0.02 | 0.06 | 0.46 | 0.71 | 0.53 | 0.07 | 0.02 | 0.05 | 0.04 | 0.01 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0.01 | 0.04 | 0.01 | 0.38 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 |
| MKAR | 0.57 | 0.25 | 0.03 | 0 | 0.02 | 0.03 | 0.07 | 0.08 | 0.01 | 0.06 | 0.11 | 0.06 | 0 | 0.24 | 0.55 | 0.72 | 0.78 | 0.67 | 0.77 | 0.65 | 0.91 | 0.89 | 0.94 | 0.95 | 0.95 | 0.97 | 0.96 | 1.07 | 0.83 | 0.86 | 0.82 | 0.28 | 0.48 | 0.12 | 0.13 | 0.07 | 0.52 | 0.13 | 0.6 | 0.58 | 0.61 | 0.4 | 0.06 | 0.2 | 0.07 | 0.92 | 0.88 | 0.9 | 0.07 | 0.14 |
| NOA | 0.12 | 0.07 | 0.05 | 0.01 | 0.14 | 0.03 | 0.04 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0.01 | 0 | 0 | 0 | 0.06 | 0.16 | 0.09 | 0.08 | 0.03 | 0 | 0 | 0.1 | 0.13 | 0.27 | 0.02 | 0.21 | 0.27 | 0.3 | 0.11 | 0 | 0.01 | 0.06 | 0.76 | 0.07 | 0 | 0.02 | 0.43 | 0.16 | 0.08 | 0 | 0 | 0 | 0.02 | 0.28 | 0.43 | 0.62 | 0 |
| NRIK | 0.02 | 0.01 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0.01 | 0 | 0.01 | 0.01 | 0.03 | 0.02 | 0 | 0 | 0.03 | 0.01 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.14 | 0.02 | 0.05 | 0.01 | 0.01 | 0.01 | 0 | 0.01 | 0.02 | 0 | 0 |
| NVAR | 0.32 | 0.68 | 1.23 | 0.96 | 0.9 | 0.74 | 0.31 | 0.19 | 0.08 | 0.04 | 0.01 | 0.23 | 0.29 | 0.26 | 0.13 | 0.01 | 0.33 | 0.27 | 0.12 | 0.07 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.12 | 0.03 | 0.51 | 0.25 | 0 | 0.02 | 0 | 0.35 | 0.07 | 0.12 | 0.38 | 0.39 | 0.75 | 0.04 | 0.01 | 0 | 0 | 0 | 0 |
| PDAR | 0.44 | 0.84 | 0.94 | 0.94 | 0.52 | 0.59 | 0.57 | 0.19 | 0.21 | 0.01 | 0 | 0.12 | 0.25 | 0.01 | 0.01 | 0 | 0.01 | 0.05 | 0.13 | 0.04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.1 | 0.4 | 0.03 | 1.23 | 0.5 | 0.03 | 0.03 | 0 | 0.3 | 0.31 | 0.14 | 0.59 | 0.42 | 0.9 | 0.01 | 0 | 0 | 0 | 0 | 0 |
| PETK | 0.45 | 0.02 | 0.03 | 0.03 | 0.01 | 0 | 0 | 0 | 0.01 | 0 | 0.02 | 0.09 | 0.08 | 0.07 | 0.09 | 0.04 | 0.01 | 0.02 | 0.26 | 0.01 | 0.01 | 0.07 | 0.05 | 0.04 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0.07 | 0 | 0.12 | 0.06 | 0.04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PLCA | 0 | 0 | 0 | 0.04 | 0.07 | 0.11 | 0.09 | 0.57 | 1.08 | 0.16 | 0.07 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 | 0.02 | 0 | 0.25 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.28 | 0.16 | 0.08 | 0 | 0 | 0 | 0 | 0 |
| ROSC | 0 | 0 | 0 | 0 | 0.07 | 0.13 | 0.69 | 0.06 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0.03 | 0 | 0 | 0 | 0 | 0 |
| SCHQ | 0.02 | 0.01 | 0.02 | 0.01 | 0.12 | 0.33 | 0.18 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0.01 | 0.07 | 0 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 | 0.12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SONM | 0.4 | 0.06 | 0.16 | 0.02 | 0 | 0.03 | 0.01 | 0.01 | 0.02 | 0 | 0 | 0.01 | 0.02 | 0.32 | 0.44 | 0.16 | 0.38 | 0.32 | 0.37 | 0.61 | 0.64 | 0.36 | 0.26 | 0.28 | 0.39 | 0.7 | 0.69 | 0.1 | 0.11 | 0.18 | 0.21 | 0.12 | 0.3 | 0.03 | 0.06 | 0.03 | 0.16 | 0.05 | 0.35 | 0.18 | 0.46 | 0.27 | 0.06 | 0.06 | 0 | 0.56 | 0.17 | 0.21 | 0.01 | 0 |
| STKA | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0 | 0 | 0.01 | 0.21 | 0.43 | 0.57 | 0.55 | 0.21 | 0.22 | 0.1 | 0.06 | 0 | 0.06 | 0.08 | 0.31 | 0.36 | 0.27 | 0.02 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0.2 | 0 | 0 | 0 | 0 | 0.98 | 0.09 | 0 | 0.02 | 0 | 0.14 | 0 | 0.43 | 0.06 | 0 | 0 | 0 | 0 |
| TORD | 0 | 0 | 0 | 0 | 0.05 | 0.16 | 0.29 | 0.87 | 0.54 | 0.94 | 0.05 | 0.01 | 0 | 0.02 | 0 | 0.07 | 0.02 | 0.01 | 0 | 0 | 0 | 0.07 | 0.04 | 0.04 | 0.07 | 0.18 | 0.4 | 0.02 | 0.58 | 0.75 | 0.75 | 0.85 | 0.3 | 0 | 0.94 | 0.1 | 0.67 | 0.01 | 0.05 | 0.5 | 0 | 0.02 | 0.07 | 0.01 | 0.12 | 0.03 | 0.59 | 0.57 | 0.02 | 0.29 |
| TXAR | 0.63 | 0.49 | 0.79 | 1.07 | 0.95 | 0.88 | 0.73 | 0.47 | 0.69 | 0 | 0 | 0.19 | 0.42 | 0.04 | 0 | 0 | 0 | 0.07 | 0.25 | 0.01 | 0 | 0.02 | 0.01 | 0.03 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.06 | 0.38 | 0.05 | 0.79 | 0.44 | 0.03 | 0.02 | 0.01 | 0.3 | 0.29 | 0.14 | 0.41 | 0.41 | 0.79 | 0.03 | 0.04 | 0 | 0 | 0.14 |
| ULM | 0.01 | 0.47 | 0.29 | 0.11 | 0.17 | 0.35 | 0.19 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0 | 0.87 | 0.13 | 0 | 0 | 0.02 | 0.01 | 0.01 | 0.13 | 0.02 | 0.23 | 0 | 0 | 0 | 0 | 0 | 0 |
| USRK | 0.01 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.01 | 0.04 | 0.03 | 0.02 | 0.03 | 0.06 | 0.21 | 0.08 | 0.06 | 0.04 | 0.04 | 0.06 | 0 | 0.01 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.04 | 0 | 0.76 | 0.03 | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |
| VNDA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.08 | 0.59 | 0.08 | 0.08 | 0.08 | 0.15 | 0.09 | 0.14 | 0.02 | 0 | 0 | 0 | 0 | 0.02 | 0.05 | 0.04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0.25 | 0 | 0 | 0 | 0.01 | 0.02 | 0.07 | 0 | 0 | 0 | 0.2 | 0 | 0.85 | 0 | 0 | 0 | 0 | 1.14 |
| WRA | 0.13 | 0 | 0.01 | 0.04 | 0.19 | 0.43 | 0.02 | 0.35 | 0.02 | 0.03 | 0.99 | 0.99 | 0.98 | 0.96 | 0.98 | 0.99 | 0.89 | 0.95 | 0.7 | 0.81 | 0.91 | 0.95 | 0.99 | 0.99 | 0.85 | 0.82 | 0.34 | 0.03 | 0.06 | 0.01 | 0 | 0.04 | 0.9 | 0.01 | 0.19 | 0 | 0.03 | 1.02 | 0.82 | 0.01 | 0.48 | 0.08 | 0.51 | 0.08 | 0.96 | 0.92 | 0.44 | 0.38 | 0 | 1 |
| YKA | 0.61 | 0.89 | 0.66 | 0.34 | 0.63 | 0.66 | 0.67 | 0.27 | 0 | 0.36 | 0.08 | 0.03 | 0.05 | 0.08 | 0.11 | 0.02 | 0.4 | 0.27 | 0.17 | 0.25 | 0.38 | 0.11 | 0 | 0.01 | 0.01 | 0.11 | 0.24 | 0.02 | 0.18 | 0.12 | 0.28 | 0.32 | 0.04 | 0.38 | 0.31 | 0.1 | 0.02 | 0.02 | 0.33 | 0.41 | 0.19 | 0.87 | 0.15 | 0.72 | 0.11 | 0 | 0.22 | 0.32 | 0.04 | 0 |
| ZALV | 0.16 | 0.07 | 0.05 | 0 | 0 | 0 | 0 | 0.08 | 0.05 | 0.14 | 0.01 | 0.01 | 0 | 0.03 | 0.21 | 0.17 | 0.24 | 0.18 | 0.33 | 0.19 | 0.65 | 0.29 | 0.13 | 0.28 | 0.4 | 0.59 | 0.72 | 1.01 | 0.62 | 0.54 | 0.32 | 0.05 | 0.36 | 0.06 | 0 | 0.02 | 0.22 | 0.02 | 0.23 | 0.11 | 0.18 | 0.23 | 0.04 | 0.03 | 0 | 0.69 | 0.78 | 0.94 | 0.02 | 0 |

# Spot Check Tool Background
## Generalized approach to template design



## Synthetic/Subspace master event extension: dimensionality reduction with multidimensional templates + ℕ-D noise reduction




**High-order dimensionality reduction methods**

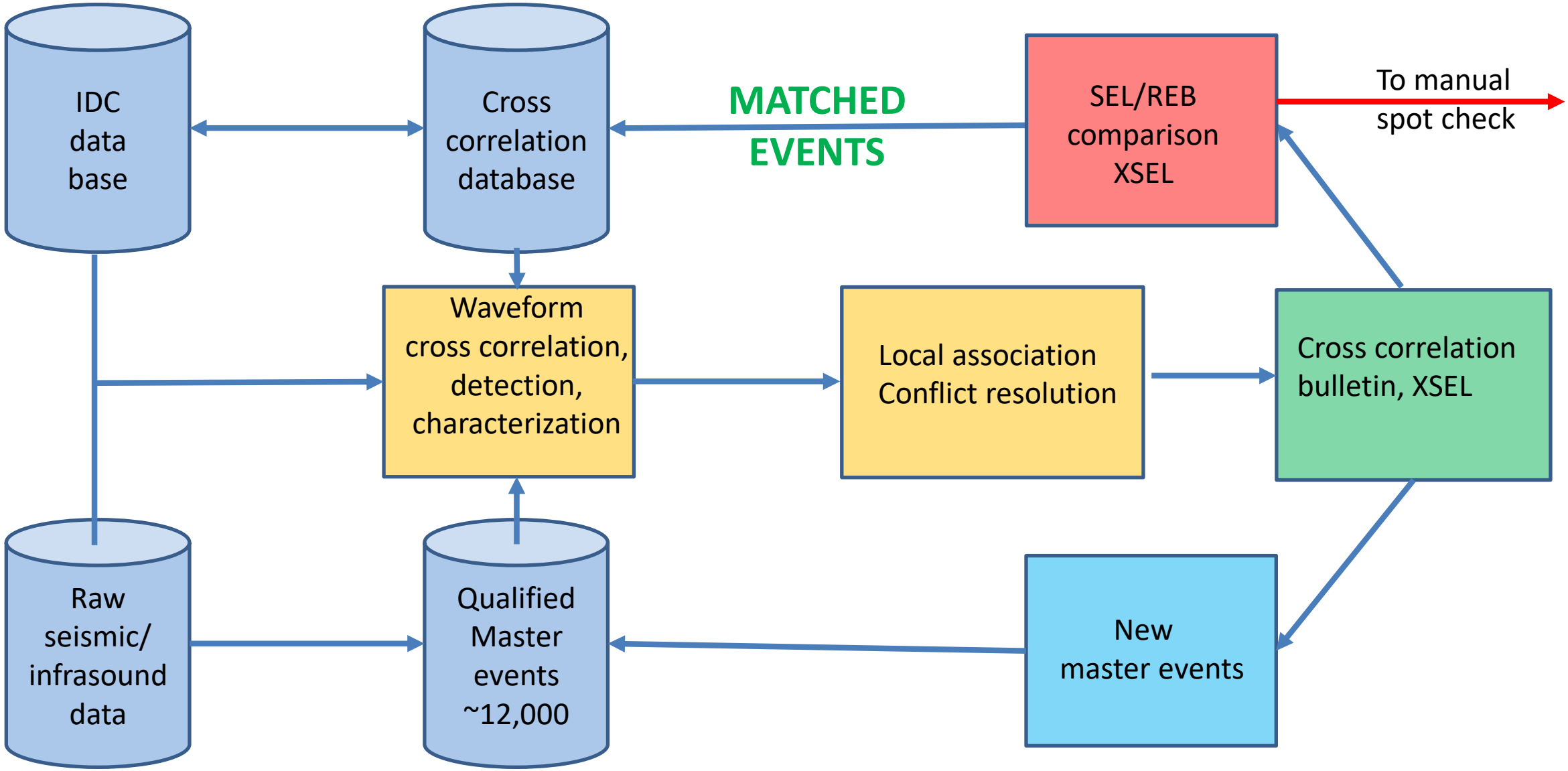
a. Multidimensional discrete cosine transform (DCT)
b. Tensor interpolation
c. Tensor SVD
d. 2D Fourier transform
e. Hyper-complex decomposition of data from 3C stations

**Object**

a. 3C station
b. Vertical array stations
c. 3-C array station
d. Inhomogeneous network (global and station templates)

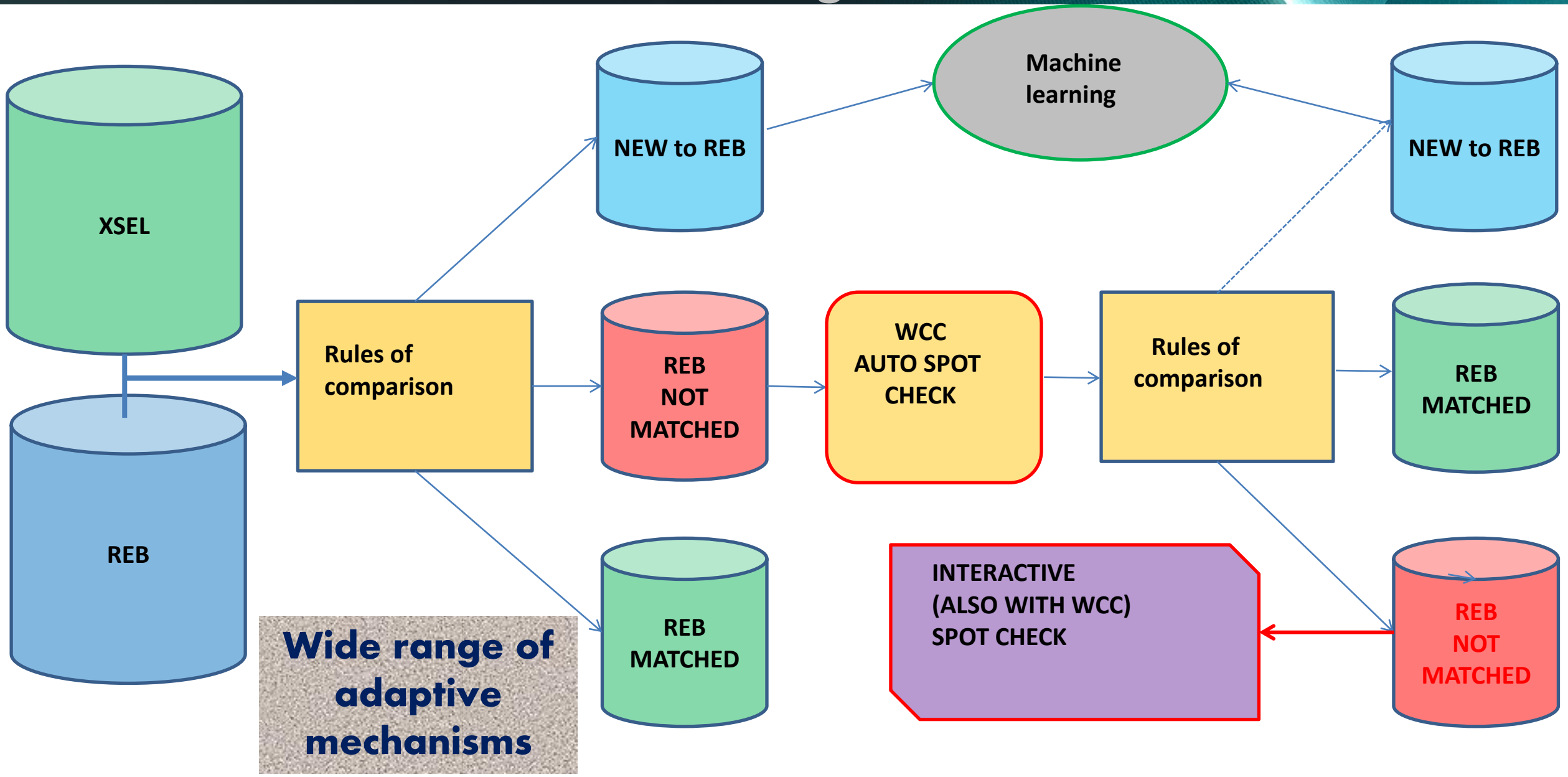
# Spot Check Tool Diagram
## Automatic Spot Check Mode (best practice)





# Spot Check Tool Diagram
## Overall Processing





# Spot Check Tool Architecture

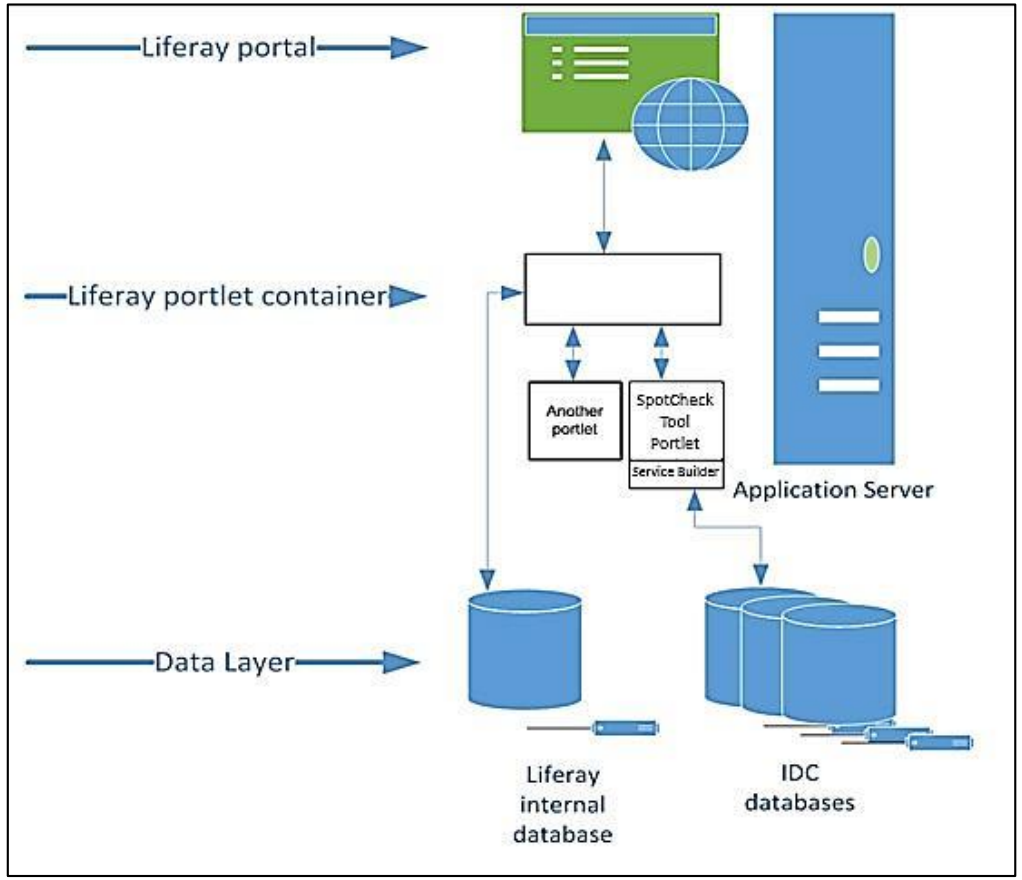
- *Information backbone*: historical IDC database, allows for testing current event hypotheses with the archived event bulletins using master event approach
- *SCT frontend*: Liferay IDC portal; allows access to the tool to the IR, lead analysts and wider (authorized) CTBT expert community
- *SCT computational backend*:
  - distributed, including servers and workstations
  - Presently SCT-prototype code
  - To migrate to the GPU-server in future

# What is SCT front-end?

LIFERAY

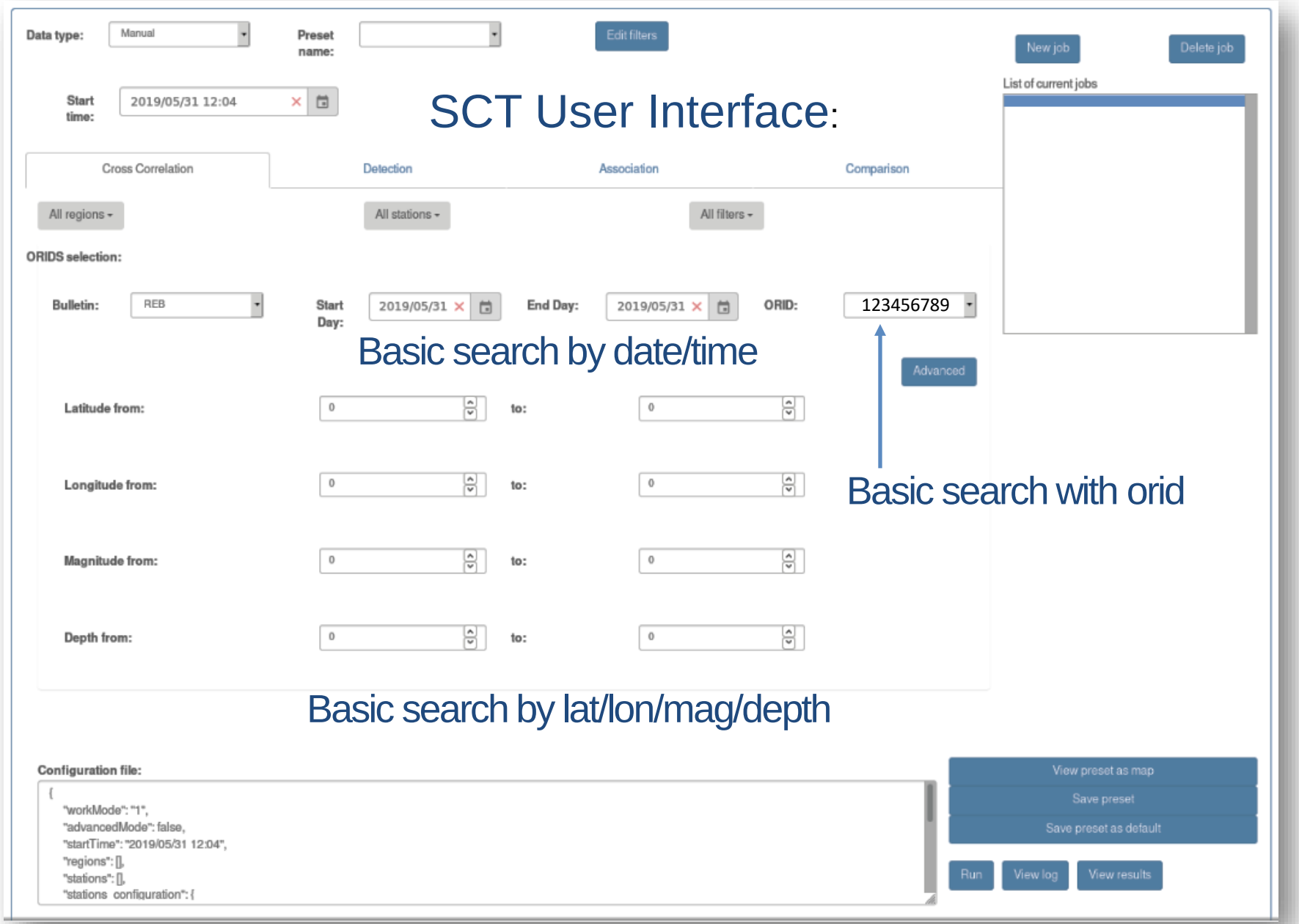
- SCT front-end is Liferay.
- Liferay is an Enterprise Portal which provides a development framework for new applications or customization (it can also provide a framework for the ETA/SS applications). Liferay Portal is developed using an open source methodology.
- Liferay Portal works in four key areas:
  - ✓ Web Content Management
  - ✓ User collaboration
  - ✓ Development Platform
  - ✓ Customization

**IDC Secure Web Portal is built with Liferay**



# Spot Check Tool Development





# Spot Check Tool Development



## SCT User Interface

### Event selection

### Station selection

### Setting up detection parameters

### Master event selection

### SCT main folders

### Comparison folder, XSEL vs. REB, XSEL vs. SEL

### Setting up filter parameters

# Spot Check Tool Development



Results filter

All regions

All stations

Start time: 2019/06/06 19:21

Duration: 5 Hour

Latitude from: 0 to: 0

Longitude from: 0 to: 0

Magnitude from: 0 to: 0

Depth from: 0 to: 0

REB event

SCT Slave

master1
74564021
Time: 03:31:30.114
Lat: 38.889259
Lon: 142.00612
Depth: 44.997543
Mag: 5.4093451

SCT Result Screen

SCT Nearest Master

Switch to Table mode

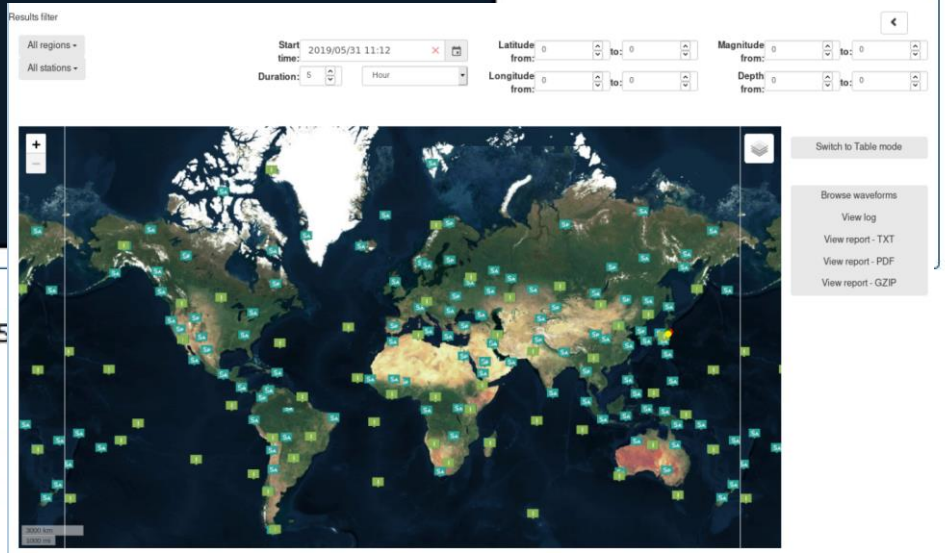
Browse waveforms

View log

View report - TXT

View report - PDF

View report - GZIP

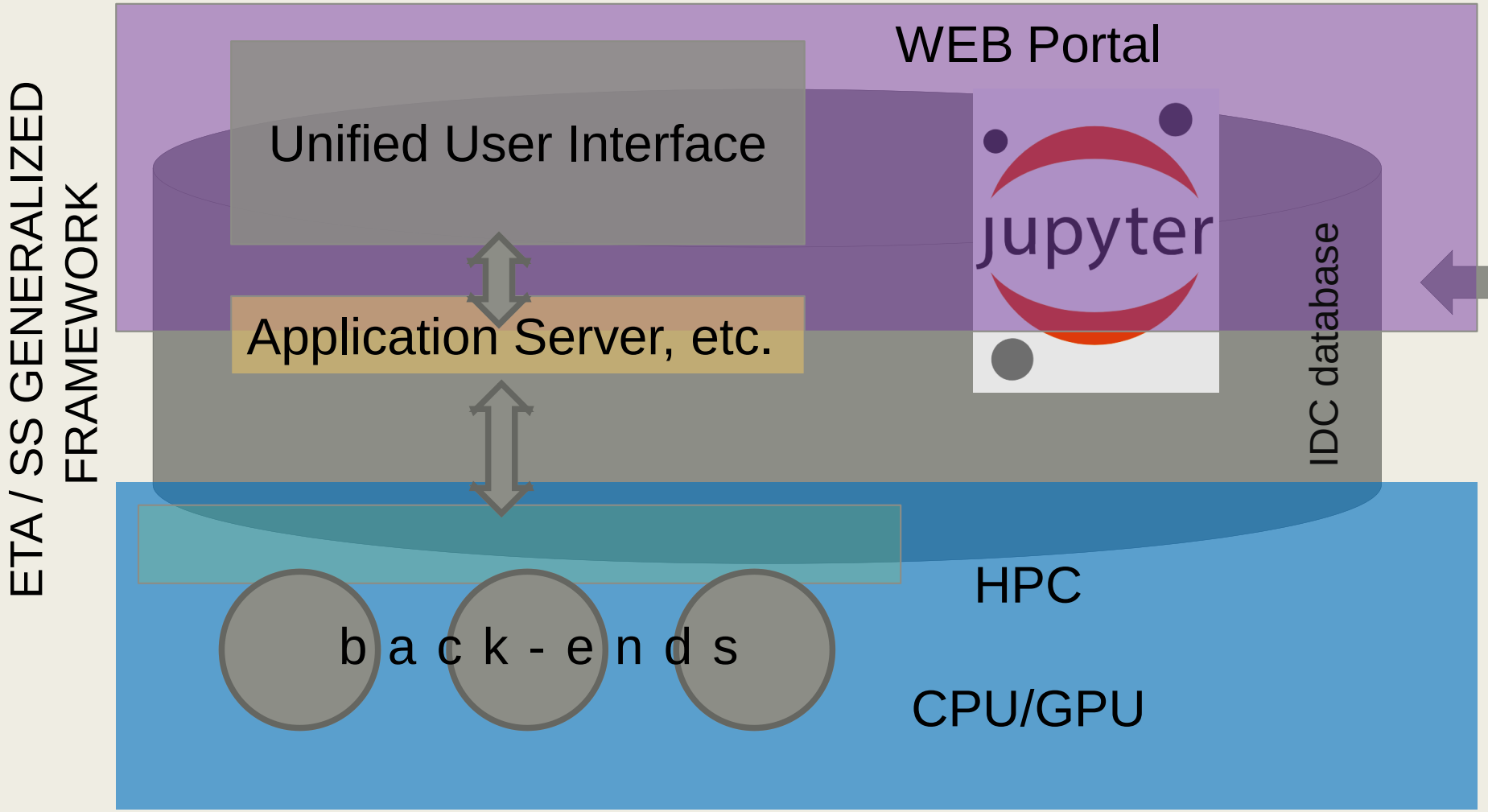


| # | MASTER | HH:MM:SS | OT_STDEV | LAT,deg | LON,deg | DEPTH,km | MB | MB_STVEV | NAS |
|---|---|---|---|---|---|---|---|---|---|
| 34 | 8021164 | 3:17: 55.78 | 0.13 | 42.050 | 42.270 | 0.0 | 3.49 | 0.27 | 3 |
| STA | DELTA | SEAZ | HH:MM:SS.SS | TIMERES,s | TT_EVENT | | SNRCC | SNR | |
| KBZ | 1.48 | 326.13 | 3:18: 24.79 | 0.164 | 28.80 | | 6.2 | 6.6 | |
| BRTR | 8.33 | 254.03 | 3:19: 41.25 | -0.019 | 106.50 | | 5.3 | 2.9 | |
| FINES | 21.82 | 336.51 | 3:22: 48.46 | -0.145 | 293.88 | | 4.4 | 2.3 | |

# Spot Check Tool Additional Features

- National event check (in a manner of national event screening) tool
- Not just an Independent Reviewer tool but an Expert Technical Analysis (ETA) or Special Study (SS) tool as well.
- A developed infrastructure can be utilized by another ETA/SS tools considering the *Liferay* as a user interface provider. In other words, current development provides the encapsulation framework for ETA/SS methods.
- A State Requested Method Reports (SRMR) of the ETA can also be generated using this approach if the NDC-supplied methods are hosted within given frameworks.

# SCT generalized architecture




Back-end code:

- Extended screening
- Extended event review
- Other

# Conclusion:

- Developed architecture hosts a Spot Check Tool back-end and provide a flexible User Interface for configuring automatic and interactive SCT and output results according to the IDC formats and standards
- A tool for the Review Officer for in depth analysis of historical (REB) and real-time (SEL1-SEL3) events
- A tool for the Expert Technical Analysis and Updated Event Bulletin (UEB) production
- Adaptive mechanisms widely used in the SCT allow for continuous incorporation of new information (e.g. machine learning based on valid/invalid event classification by analysts) into interactive and automatic processing also with daily increasing number of master events
- A cross correlation based matched filter detector provides a higher sensitivity and resolution with a competitive false alert rate

# THANK YOU

# Spot Check Tool Additional Information

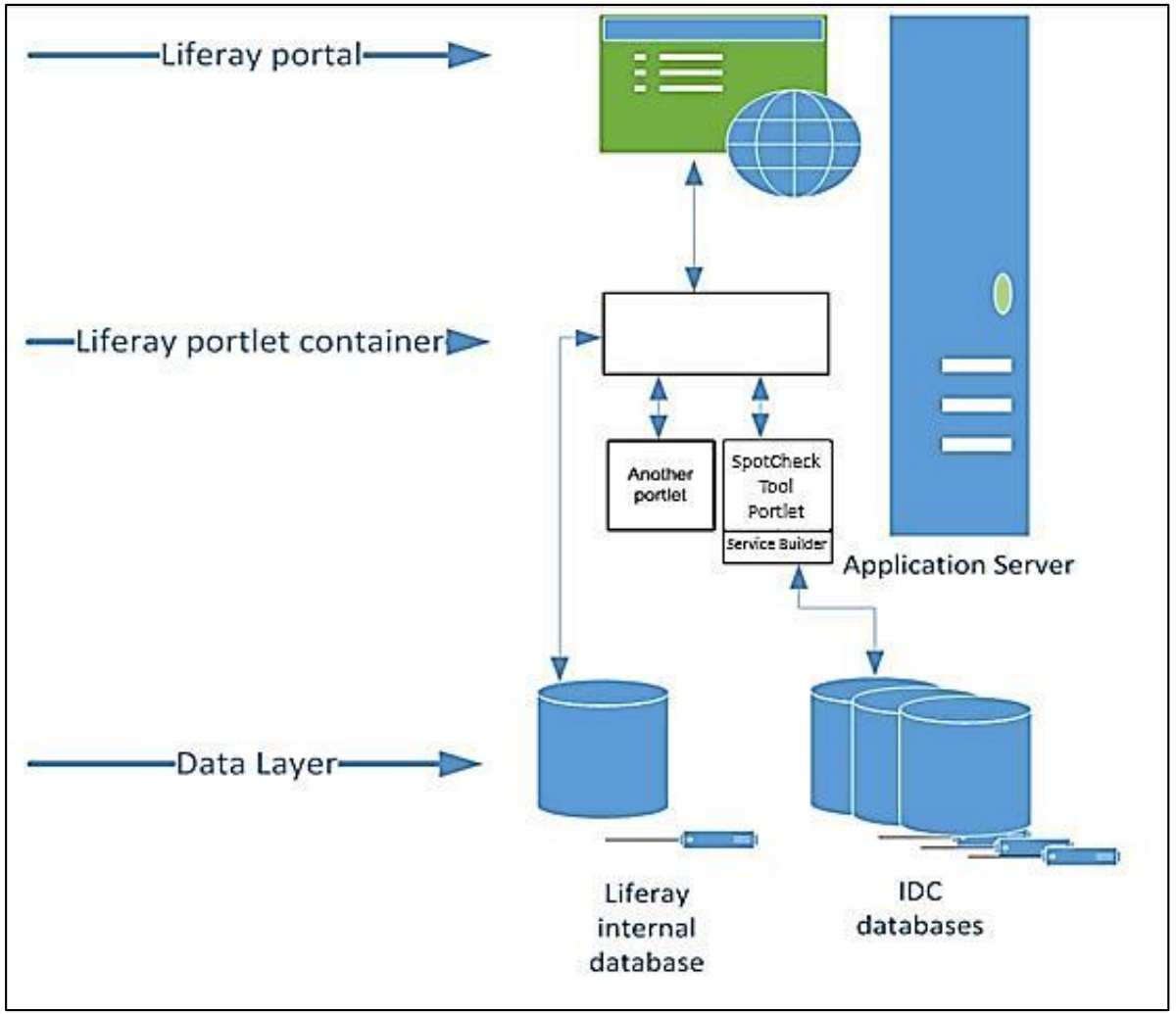
# Liferay – general scheme

**Portal** – provides general services like authentication, themes, email, users collaboration etc.

**Portlet container** - runtime environment for portlets using the JSR 286 Portlet specification, in which portlets are instantiated, used, and finally destroyed.

**Portlet - Web-based component** that will process requests and generate dynamic content. The end-user would essentially see a portlet as being a specialized content area within a Web page that occupies a small window in the portal page. Depending on the content nature of the Web site providing the portlet you could use this area to receive different types of information. The portlet provides users with the capability to customize the content, appearance and position of the portlet.

**Service Builder** – Liferay built-in Object-Relational Mapping System



# SCT Data Flow diagram

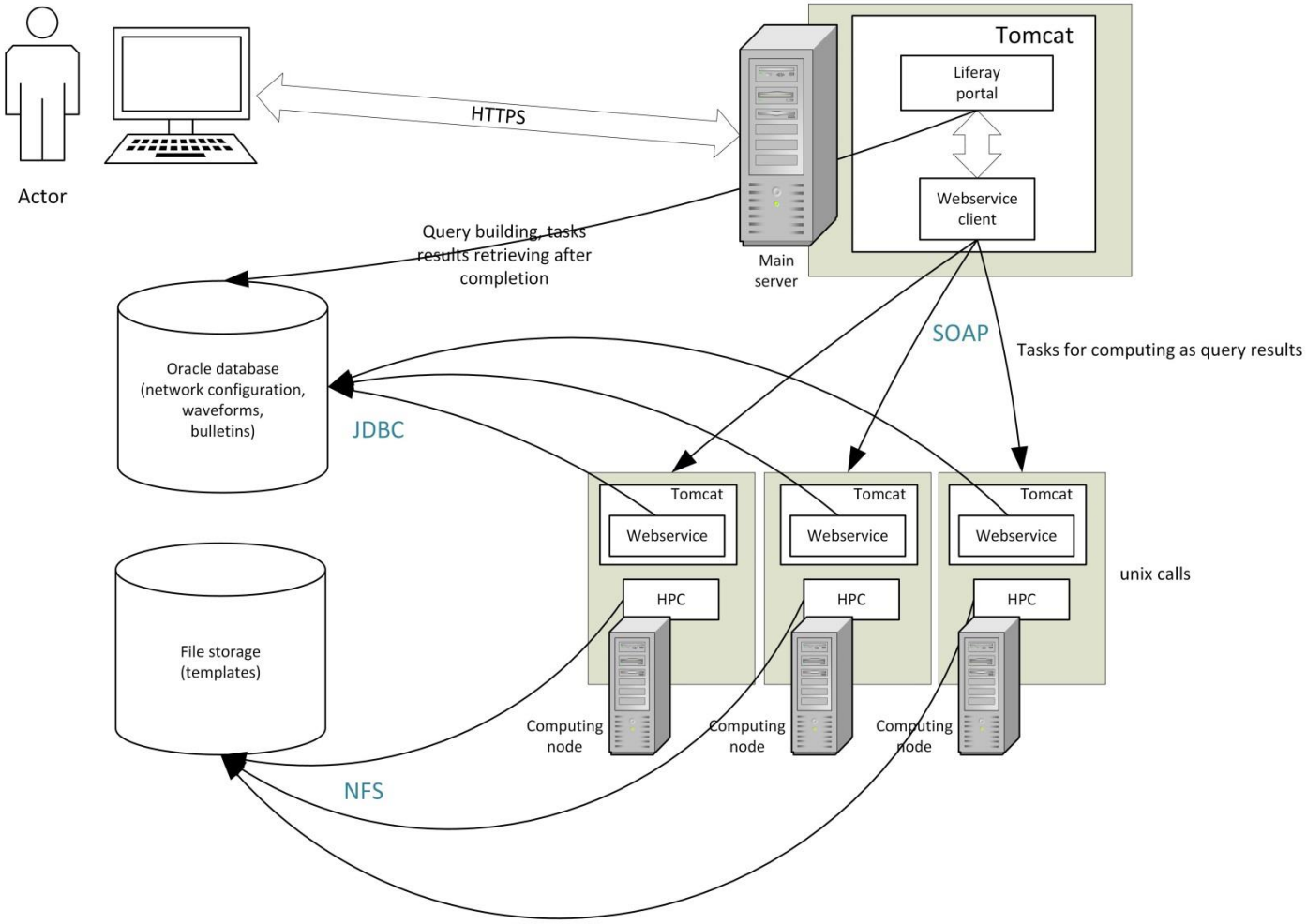
Data Flow diagram shows system from point of required computing nodes, protocols between them and physical connections.

Tomcat – Java servlet container used to run Liferay itself and other components, like web services.

Several computing nodes can be used to balance load. Main portlet is responsible for preparing tasks for them and assembling results.

*Servlet - a small Java program that runs within a Web server, handle clients' requests and return a customized or dynamic response for each request, usually across HTTP.*

*SOAP (Simple Object Access Protocol) is a messaging protocol that allows programs that run on disparate operating to communicate using HTTP and XML.*



# Spot Check Tool Background

## Adaptive Mechanisms



- INCLUSION OF NEW MASTER EVENTS IN THE SET FOR AUTOMATIC PROCESSING AFTER AUTOMATIC SPOT CHECK PROCEDURE
- ADDING POTENTIAL MASTER EVENTS FROM THE MOST RECENT REB FOR SPOT CHECK
- 
- SELECTION OF TEMPORARY MASTER EVENTS FROM GLOBAL SYNTHETIC MASTER GRID (OR SEL3) IN AREAS WITHOUT HISTORICAL SEISMICITY (e.g., FRESH FAULTS)
- REGULAR RECALCUALTION/SELECTION OF MASTER EVENTS FOR AUTOMATIC PROCESSING
- TUNING DETECTION THRESHOLDS FOR EACH MASTER/STATION PAIR BY RATE OF FALSE ALARMS (NOT ASSOCIATED PHASES) PER DAY (100-200). TUNING TEMPLATE LENGTH (4s to 200 s) TO HIGHEST SNRCC VALUE DEPENDING ON MASTER/STATION/PHASE COMBINATION/ ALSO FOR INFRASOUND
- TUNING ASSOCIATION/CONFLICT RESOLUTION PARAMETERS BY REB/XSEL COMPARISON
- MACHINE LEARNING USING NEW XSEL (REB) EVENTS APPROVED/REJECTED BY ANALYSTS

Spot Check Tool Background

# Spot Check Tool Results (incl. infrasound)



## XSEL For Earthquakes

| # | MASTER | HH:MM:SS | OT_STDEV | LAT,deg | LON,deg | DEPTH,km | MB | MB_STVEV | NASS | NEW/REB | REB_ORID |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 8021164 | 3:17: 55.78 | 0.13 | 42.050 | 42.270 | 0.0 | 3.49 | 0.27 | 3 | NEW | 0 |

| STA | DELTA | SEAZ | HH:MM:SS.SS | TIMERES,s | TT_EVENT | SNRCC | SNR | dRM | CC | STA_WEIGHT |
|---|---|---|---|---|---|---|---|---|---|---|
| KBZ | 1.48 | 326.13 | 3:18: 24.79 | 0.164 | 28.80 | 6.2 | 6.6 | 0.185 | 0.157 | 3 |
| BRTR | 8.33 | 254.03 | 3:19: 41.25 | -0.019 | 106.50 | 5.3 | 2.9 | -0.434 | 0.140 | 7 |
| FINES | 21.82 | 336.51 | 3:22: 48.46 | -0.145 | 293.88 | 4.4 | 2.3 | -0.329 | 0.287 | 7 |

| # | MASTER | HH:MM:SS | OT_STDEV | LAT,deg | LON,deg | DEPTH,km | MB | MB_STVEV | NASS | NEW/REB | REB_ORID |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 15478739 | 3:31: 54.26 | 0.92 | 50.840 | 155.430 | 133.0 | 4.03 | 0.46 | 8 | SEL | 16341645 |

| STA | DELTA | SEAZ | HH:MM:SS.SS | TIMERES,s | TT_EVENT | SNRCC | SNR | dRM | CC | STA_WEIGHT |
|---|---|---|---|---|---|---|---|---|---|---|
| MJAR | 18.38 | 228.21 | 3:36: 4.75 | -0.581 | 249.76 | 4.9 | 15.3 | 0.166 | 0.254 | 7 |
| ILAR | 32.97 | 41.84 | 3:38: 11.31 | -0.380 | 377.32 | 4.1 | 3.5 | -0.936 | 0.220 | 6 |
| ZALV | 41.78 | 303.31 | 3:39: 27.77 | -0.215 | 454.02 | 4.6 | 4.4 | -0.375 | 0.254 | 4 |
| MKAR | 46.64 | 295.40 | 3:40: 7.32 | -0.027 | 493.57 | 8.4 | 16.8 | -0.601 | 0.492 | 7 |
| FINES | 61.47 | 334.90 | 3:41: 52.79 | 0.463 | 598.05 | 4.2 | 2.4 | -0.694 | 0.235 | 5 |
| PDAR | 61.60 | 56.48 | 3:41: 58.07 | 1.535 | 603.37 | 4.9 | 5.7 | -0.379 | 0.395 | 4 |
| TXAR | 74.60 | 62.71 | 3:43: 14.53 | -1.681 | 681.10 | 8.1 | 10.8 | -0.754 | 0.470 | 5 |
| ASAR | 75.97 | 200.09 | 3:43: 30.35 | 0.884 | 695.02 | 4.5 | 16.6 | 0.505 | 0.285 | 6 |

| # | MASTER | HH:MM:SS | OT_STDEV | LAT,deg | LON,deg | DEPTH,km | MB | MB_STVEV | NASS | NEW/REB | REB_ORID |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 13421400 | 3:40: 33.69 | 2.00 | -18.400 | -179.810 | 618.0 | 4.81 | 0.25 | 10 | REB | 16342096 |

| STA | DELTA | SEAZ | HH:MM:SS.SS | TIMERES,s | TT_EVENT | SNRCC | SNR | dRM | CC | STA_WEIGHT |
|---|---|---|---|---|---|---|---|---|---|---|
| STKA | 38.29 | 241.40 | 3:47: 1.29 | -2.965 | 387.91 | 9.2 | 24.8 | 3.737 | 0.837 | 7 |
| WRA | 44.35 | 259.85 | 3:47: 40.84 | -1.620 | 428.38 | 11.1 | 344.0 | 0.578 | 0.442 | 9 |
| ASAR | 44.49 | 254.53 | 3:47: 46.11 | 2.783 | 433.43 | 14.6 | 757.3 | 0.833 | 0.834 | 9 |
| NVAR | 79.79 | 43.91 | 3:51: 46.05 | -1.383 | 672.46 | 18.1 | 189.9 | 0.606 | 0.749 | 4 |
| ILAR | 86.22 | 13.07 | 3:52: 9.79 | -1.153 | 696.48 | 7.9 | 182.7 | 0.792 | 0.459 | 5 |
| CMAR | 88.76 | 289.77 | 3:52: 20.33 | -2.226 | 706.08 | 12.1 | 71.3 | 0.801 | 0.470 | 3 |
| TXAR | 86.35 | 57.68 | 3:52: 20.33 | 1.700 | 706.61 | 19.9 | 350.5 | 0.519 | 0.805 | 5 |
| PDAR | 87.72 | 43.51 | 3:52: 22.97 | 2.621 | 710.18 | 14.0 | 113.1 | 0.282 | 0.599 | 3 |
| ARCES | 126.56 | 349.68 | 3:58: 26.84 | 1.505 | 1074.01 | 8.4 | 22.7 | 1.033 | 0.633 | 3 |
| GERES | 147.83 | 344.61 | 3:59: 11.66 | 0.739 | 1117.21 | 11.9 | 239.4 | 1.145 | 0.633 | 5 |

## XSEL For Quarry Blasts

| # | MASTER | HH:MM:SS | OT_STDEV | LAT,deg | LON,deg | DEPTH,km | MB | MB_STVEV | NASS | NEW/REB | REB ORID | SEIS_REG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 9274056 | 1:14: 0.23 | 0.82 | 55.379 | 86.677 | 0.0 | -0.67 | 0.52 | 3 | NEW | 0 | 28 |

| #EV | #STA | MASTER | STA | ARRTIME | TT | TIMERES,s | SNRCC | SNR | CC | dRM | NA | NA | SLOW | SEAZ | DELTA | STA_ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 1 | 9274056 | MKAR | 1538270170.875 | 131.950 | -0.820 | 3.53 | 2.84 | 0.1170 | -0.152 | 0.0 | 0.0 | 0.1233 | 198.60 | 9.07 | 10. |
| 11 | 2 | 9274056 | ZALV | 1538270071.425 | 30.341 | 0.820 | 4.64 | 2.63 | 0.1130 | -1.198 | 0.0 | 0.0 | 0.1237 | 213.25 | 1.80 | 9. |

1 1 I46RU arrtime= 1538270704.200 1:25: 4.69 tres= -13.43 ttime= 643.00 delta= 1.80 SNR= 3.82 SNRcc= 5.63 FKseaz=
IDCX I46RU N 1538270610.000 1:23: 29.77 IDCseaz 326.08 FKseaz 300.90 tt_diff 94.20 t_assoc 201.91

# Spot Check Tool Results (incl. infrasound)



| # | MASTER | HH:MM:SS | OT_STDEV | LAT,deg | LON,deg | DEPTH,km | MB | MB_STVEV | NASS | NEW/REB | REB_ORID |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 8021164 | 3:17: 55.78 | 0.13 | 42.050 | 42.270 | 0.0 | 3.49 | 0.27 | 3 | NEW | 0 |

| STA | DELTA | SEAZ | HH:MM:SS.SS | TIMERES,s | TT_EVENT | SNRCC | SNR | dRM | CC | STA_WEIGHT |
|---|---|---|---|---|---|---|---|---|---|---|
| KBZ | 1.48 | 326.13 | 3:18: 24.79 | 0.164 | 28.80 | 6.2 | 6.6 | 0.185 | 0.157 | 3 |
| BRTR | 8.33 | 254.03 | 3:19: 41.25 | -0.019 | 106.50 | 5.3 | 2.9 | -0.434 | 0.140 | 7 |
| FINES | 21.82 | 336.51 | 3:22: 48.46 | -0.145 | 293.88 | 4.4 | 2.3 | -0.329 | 0.287 | 7 |

# Spot Check Tool Background



## XSEL/REB Comparison

| SeisReg | REB | XSEL | Matched | Weight | | SeisReg | REB | XSEL | Matched | Weight |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 1 | 22 | | 26 | 0 | 2 | 0 | 24 |
| 2 | 0 | 3 | 0 | 24 | | 27 | 0 | 2 | 0 | 22 |
| 3 | 0 | 2 | 0 | 27 | | 28 | 0 | 31 | 0 | 25 |
| 4 | 0 | 1 | 0 | 27 | | 29 | 2 | 2 | 1 | 22 |
| 5 | 1 | 0 | 0 | 25 | | 30 | 2 | 8 | 2 | 22 |
| 6 | 0 | 0 | 0 | 23 | | 31 | 0 | 2 | 0 | 22 |
| 7 | 0 | 0 | 0 | 23 | | 32 | 5 | 7 | 1 | 17 |
| 8 | 3 | 3 | 2 | 22 | | 33 | 2 | 2 | 0 | 22 |
| 9 | 0 | 0 | 0 | 25 | | 34 | 0 | 2 | 0 | 26 |
| 10 | 1 | 1 | 0 | 24 | | 35 | 0 | 0 | 0 | 24 |
| 11 | 0 | 0 | 0 | 25 | | 36 | 7 | 8 | 0 | 28 |
| 12 | 10 | 13 | 4 | 24 | | 37 | 0 | 0 | 0 | 21 |
| 13 | 7 | 14 | 6 | 25 | | 38 | 0 | 2 | 0 | 30 |
| 14 | 3 | 7 | 3 | 24 | | 39 | 0 | 0 | 0 | 19 |
| 15 | 0 | 3 | 0 | 24 | | 40 | 0 | 13 | 0 | 20 |
| 16 | 1 | 5 | 1 | 25 | | 41 | 2 | 7 | 1 | 19 |
| 17 | 1 | 3 | 1 | 24 | | 42 | 0 | 1 | 0 | 25 |
| 18 | 5 | 7 | 4 | 23 | | 43 | 2 | 2 | 1 | 15 |
| 19 | 4 | 16 | 3 | 22 | | 44 | 0 | 0 | 0 | 25 |
| 20 | 6 | 18 | 2 | 22 | | 45 | 0 | 0 | 0 | 25 |
| 21 | 0 | 6 | 0 | 25 | | 46 | 3 | 7 | 1 | 23 |
| 22 | 1 | 3 | 0 | 26 | | 47 | 0 | 1 | 0 | 21 |
| 23 | 2 | 3 | 2 | 26 | | 48 | 1 | 0 | 0 | 22 |
| 24 | 10 | 19 | 7 | 26 | | 49 | 0 | 9 | 0 | 29 |
| 25 | 0 | 1 | 0 | 27 | | 50 | 0 | 0 | 0 | 24 |