SnT 2021
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PREPARATORY COMMISSION

Spot check of seismic and infrasound data and products at the IDC using waveform cross correlation and the REB historical events

Ivan Kitov and Christos Saragiotis
CTBTO

Poster No. P3.5-355

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POSTER

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Continuous comparison of the event hypotheses obtained in routine automatic and interactive analysis with historical events helps to improve the REB consistency and completeness

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The Reviewed Event Bulletin (REB) of the IDC is the final product of interactive analysis, but also represents a set of seismic (S), infrasound (I), and SI events, which can be used for the analysis of the REB consistency. Continuous comparison of the event hypotheses obtained in routine automatic and interactive analysis with these historical events also helps to improve the REB completeness. More than 600,000 REB events have been converted into master events (MEs) with waveform templates at IMS seismic and infrasound stations. We use the method of waveform cross-correlation (WCC) to assess the similarity between event hypotheses and the MEs at a station-by-station basis. For the hypotheses built in automatic processing (SEL1 to SEL3), only the MEs within 8 degrees from a given event hypothesis are used. For checking the REB, the best MEs within 4 degrees are used. In addition to checking the IDC bulletins, we process continuous SI data for missed events using a global set of ME selected as the most efficient in WCC detection of the historic REB events. All events obtained in the WCC processing are subject to the same spot check procedure as the SEL3 events

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Spot check of seismic and infrasound data and products at the IDC using waveform cross correlation and the REB historical events

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- Spot Check Tool based on cross correlation: concept
- Automatic cross correlation processing, XSEL
- Automatic Spot Check: XSEL, SEL*, REB, (VSEL)
- Interactive Spot Check: REB, SEL3
- Spot Check Tool: control panels
- Seismic and infrasound Spot Check approach
- Conclusion

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Spot Check (waveform cross correlation)

is waveform cross correlation processing with appropriate number of real and/or synthetic master events focused on specific area, time interval or set of events

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URGENT NEED OF SPOT CHECK TOOL: NET-VISA FINDINGS

12 from 84 REB events (14%) for April 26, 2020 have negative Net-Visa Score, i.e. contradict the Net-Visa probabilistic model based on the REB events. Possible reason – poor phase association and mislocation

#	orid	NV-Score	lat, deg	lon, deg	nass	mb	depth, km	SeisReg	evid	Smaj, km	Smin, km	Strike, deg
1	18831217	-5.67	-16.52	-177.2	7	3.623	0	13	18821069	207.9	30.9	146.3
2	18839059	-6.49	25.541	120.65	3	3.379	0	21	18821360	393.1	39.5	113.9
3	18839576	-8.92	-22.31	147.95	6	-999	0	38	18833227	58.1	32.2	81
4	18834982	-0.28	-6.35	154.59	3	3.421	0	15	18822597	215.5	55	128.2
5	18839860	-11.08	-22.67	178.75	4	2.266	650	12	18835127	272.3	109.2	166.7
6	18838974	-8.45	-14.45	167.86	3	3.355	0	14	18835121	354.9	39.3	142.7
7	18839061	-10.23	0.089	120.43	3	3.448	0	23	18835744	230.3	27.7	66.6
8	18835105	-5.80	36.913	55.04	7	2.882	0	29	18835105	55.2	19.8	5.5
9	18835192	-5.60	43.589	-105.4	10	4.085	0	34	18824150	50.6	8.5	149
10	18835251	-4.01	-3.697	150.48	3	3.364	0	15	18824211	189	29.8	123.8
11	18835739	-16.78	-6.603	154.37	4	3.367	0	15	18824620	140.9	39.9	116
12	18836332	-7.94	34.887	27.101	7	3.446	0	30	18836006	52.5	22.5	156.9

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- ***Spot Check Tool*** *development*: to facilitate a work of the Independent Reviewer (IR)
- *Underlying methodology*: waveform cross correlation
- *Processing stages*: master selection, detection using matched filter, Local Association (LA), Conflict Resolution (CR), Spot Check
- *Spot Check Modes*: Interactive and Automatic
  - Interactive: under flexible scenario developed by the IR
  - Automatic: on daily basis, building XSEL (cross correlation standard event list) bulletins and conducting automatic comparison with SELs (same day analysis) and REB (upon its completion) bulletins.

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- 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 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 event definition criteria.
- One more implementation of the master-event approach

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Routine XSEL processing: stages

WCC detection (like DFX)	Local Association (like GA)	Conflict Resolution (like GA CR)
1. Varying template length 2. Varying # of working channels (arrays and 3C) 3. Frequency bands: 0.75 Hz to 8 Hz. Choice depends on station: ARCES vs. CMAR 4. Adaptive detection (SNRcc=STA/LTA) threshold for CC traces 5. STA and LTA definition 6. STA and LTA length 7. FK using CC-traces 8. Standard detection and FK for array stations (e.g., for screening of CC-detections)	1. Area of master responsibility 2. Spacing between nodes of virtual event locations 3. Minimum number of associated stations (e.g., ndef=3) 4. Association window (e.g., 20 s) 5. Origin time residual for defining/ associated arrivals (e.g., ±3 s) 6. Weight of XSEL events > W_{min} as a sum of station probabilities (from the REB empirical statistics) 7. Quality of detections SNRcc 8. Quality of detections SNR 9. Residual of relative magnitude at stations	When two XSEL events from the same of different masters have detections at the same station within tolerance limit (LA tuning parameter), 20 s : - Compare weights, Wi and Wj, of the competing XSEL events and save this detection with the bigger event. - When Wi and Wj are equal – the number of associated stations wins - When both above equal - standard deviation of the origin time (scattering) of the competing XSEL events - Then remove events with parameters below EDC

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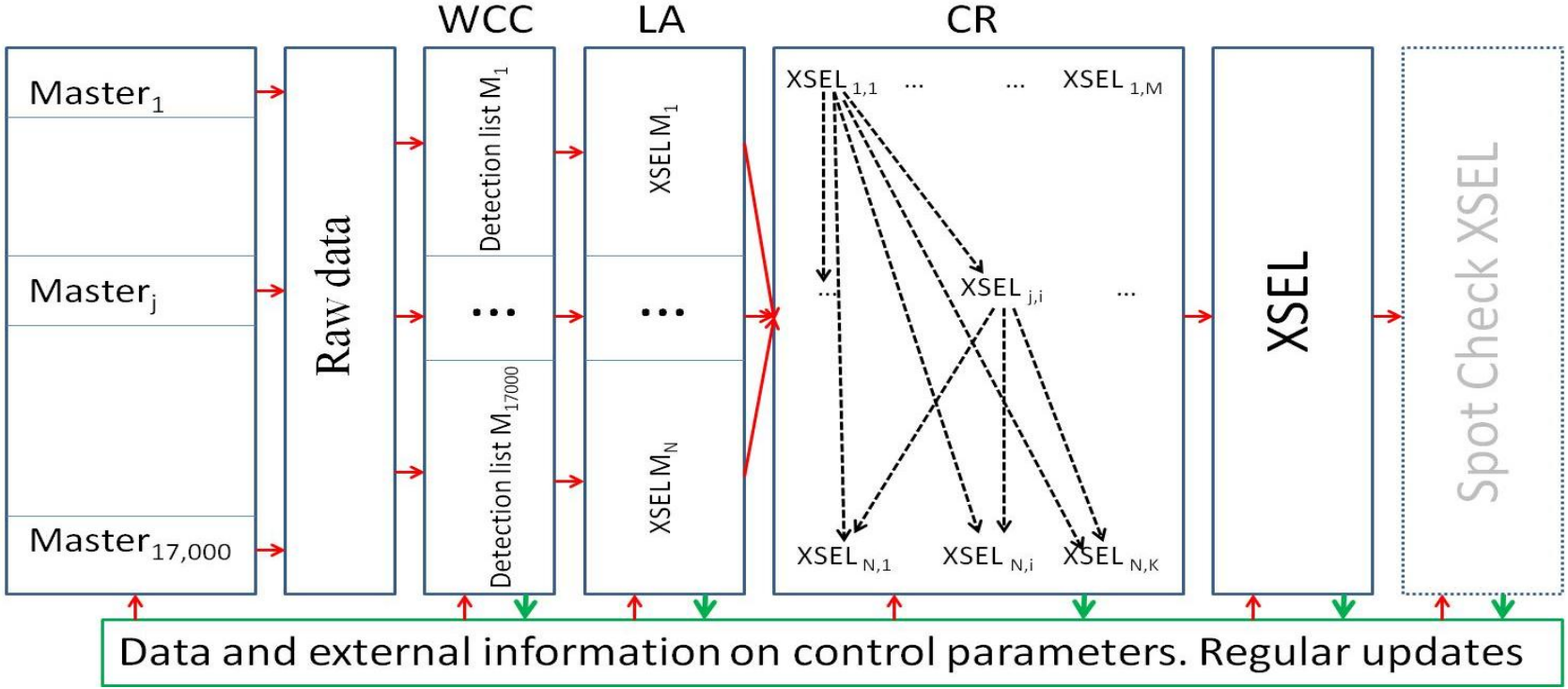
Routine XSEL processing. Spot: whole globe, all seismic and infrasound data for a day



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Routine XSEL processing limited in the number of masters and thus coverage/resolution

- Selected 13,000 master (historical REB) events distributed over the globe and depth
- Approximately 5000 events are selected by the best cross correlation with neighbours and have higher priority
- Daily WCC processing in 50 Flinn-Engdahl seismic regions
- Only the best stations are used in basic XSEL processing
- The choice of filters, correlation windows, channels of arrays stations is suboptimal
- Adaptive detection thresholds (for given setting) for each master/station pair
- Local Association within each seismic region
- Conflict Resolution between all created event hypotheses
- Creation of basic automatic XSEL – a SEL3 analogue

Additional stage is needed

Spot Check of the automatic XSEL to improve or reject XSEL event hypotheses using an extended number of master events

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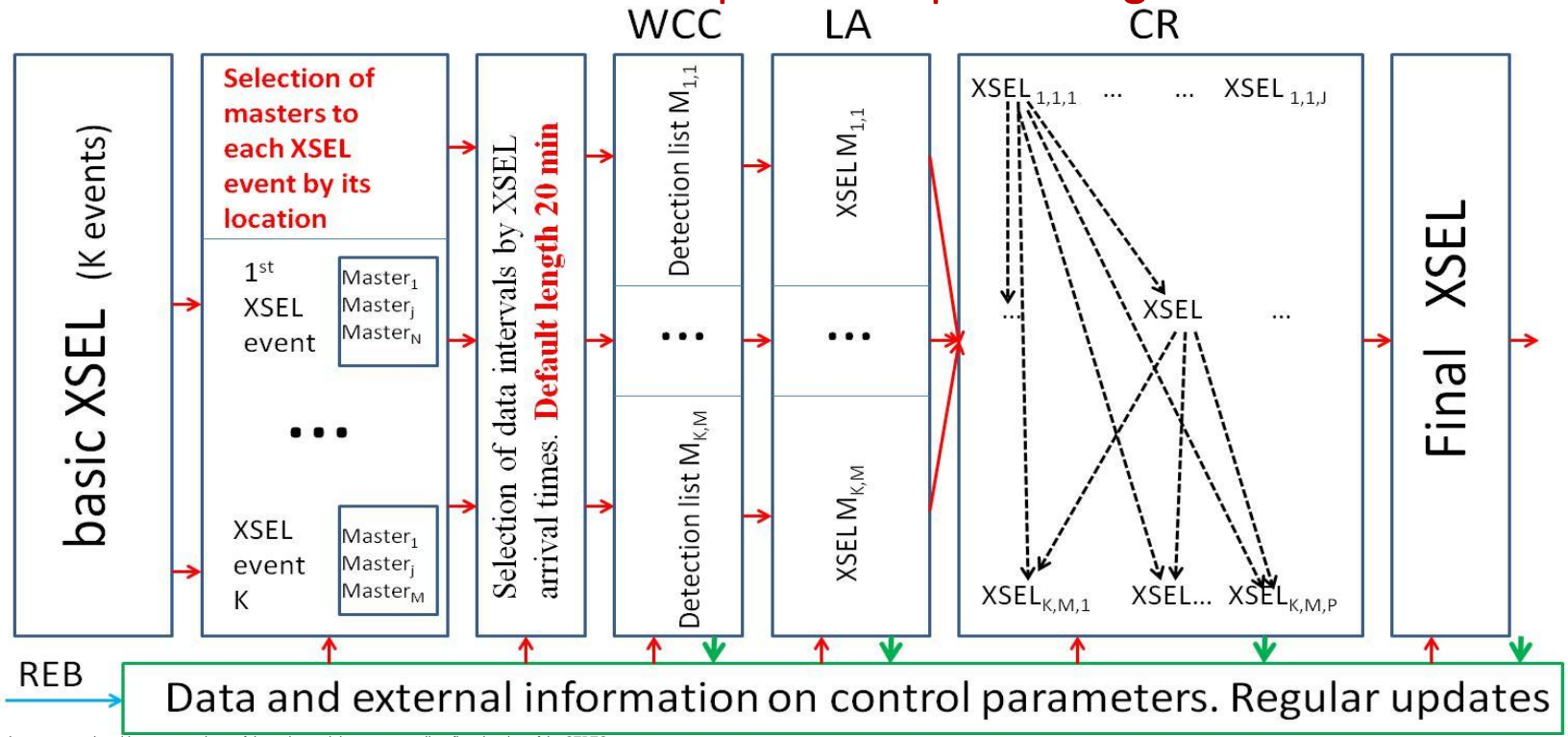
Automatic XSEL Spot Check processing



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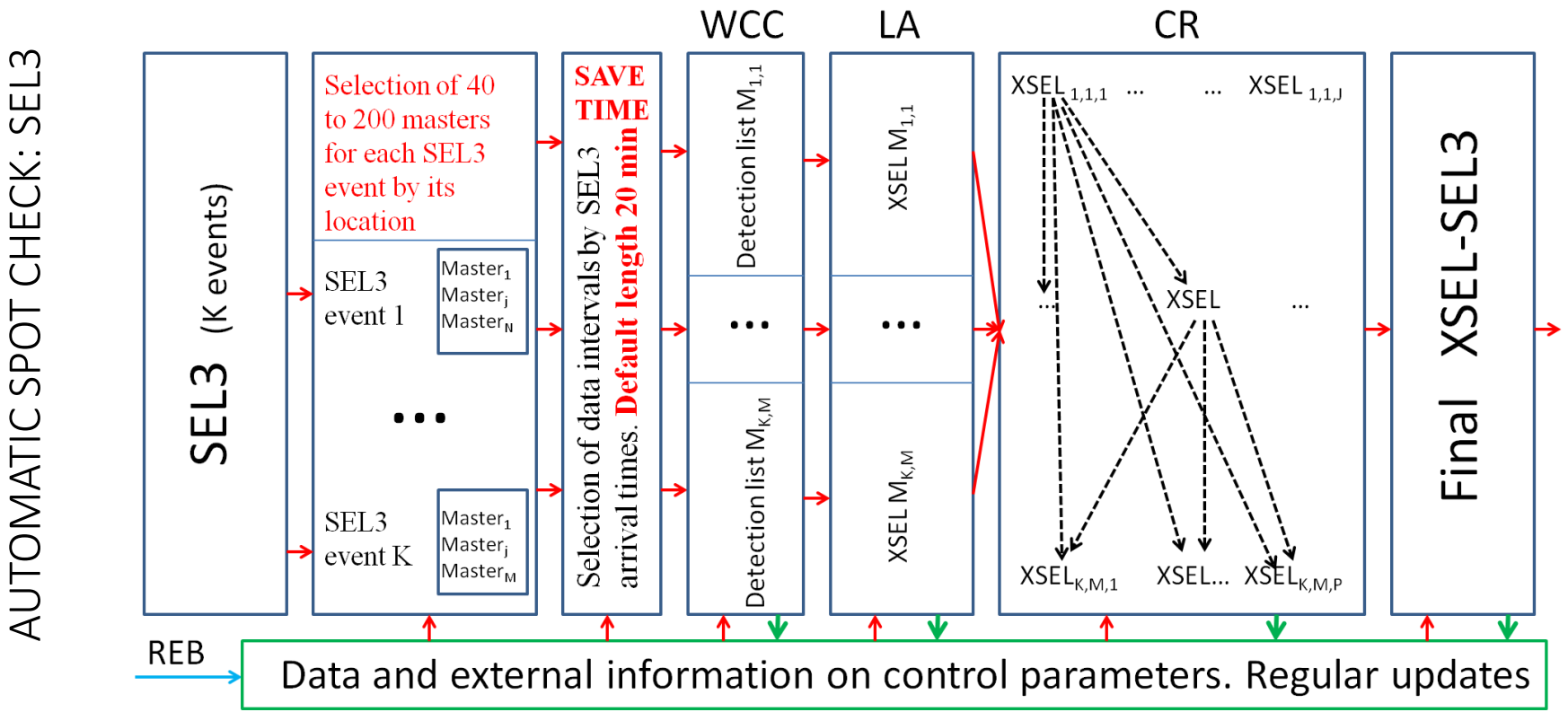

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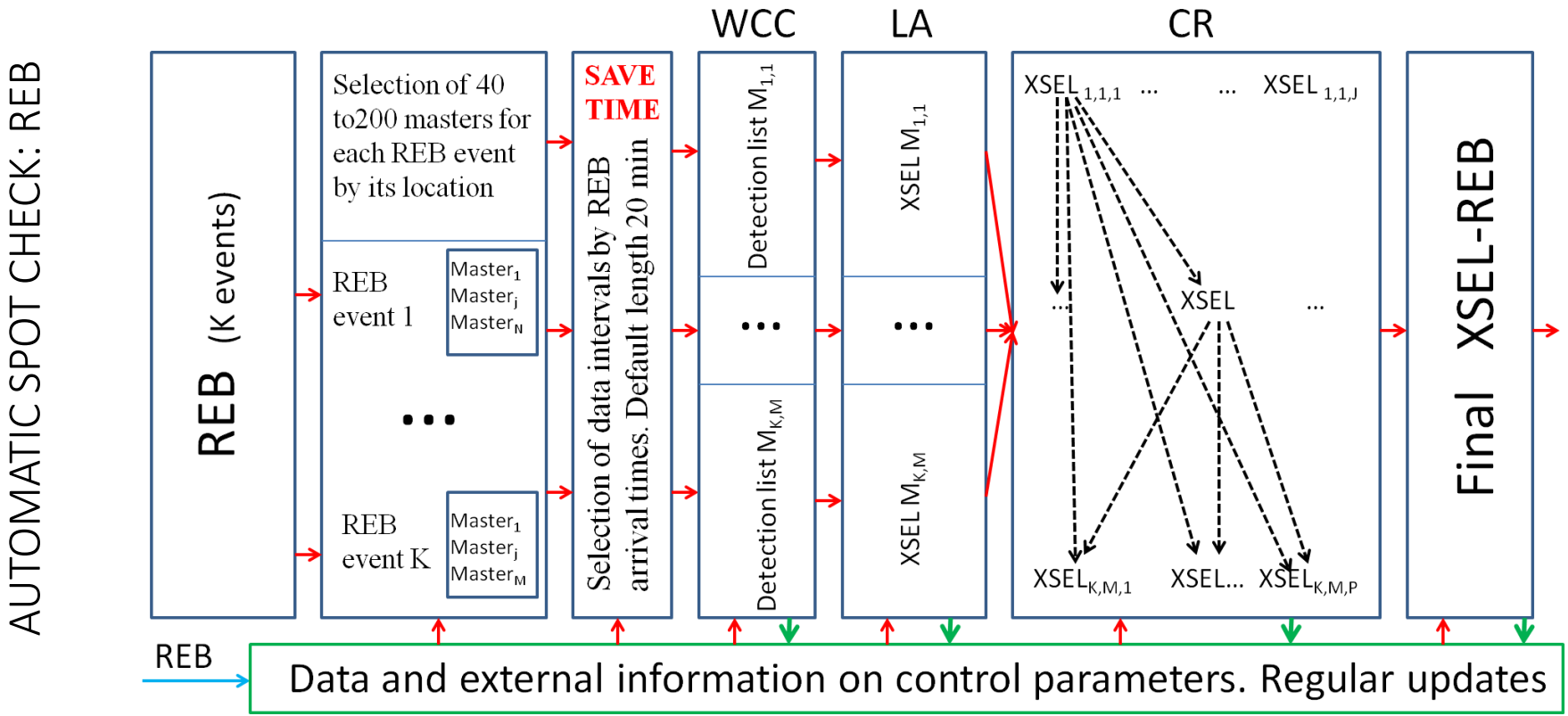

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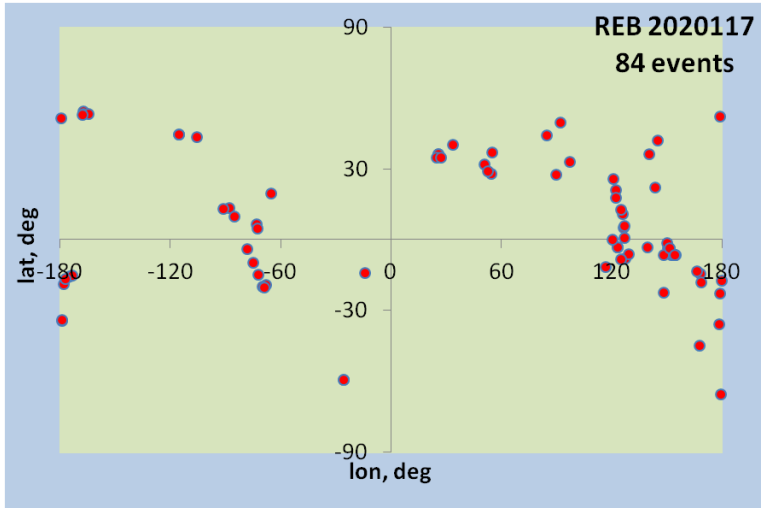
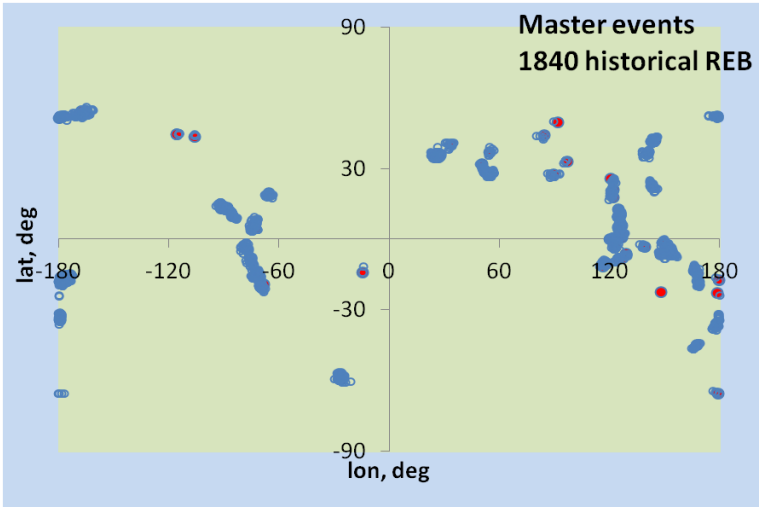
Automatic Spot Check: REB and master event selection





For all studied REB events, a set of best master (historical REB) events within 3 (predefined range) degrees is selected and the time intervals ±10 min around the measured and theoretical arrival times are processed by standard XSEL procedure. The number of master events depends on the semi-major axis (location quality) of a given REB event. The whole depth range for historical REB events is covered. 80 from 84 events were confirmed by Automatic Spot Check, i.e. (REB-ready) XSEL events matching REB events by two phases (stations) were built.

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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 broader (authorized) CTBT expert community
- *SCT computational backend*: distributed, including servers and workstations. To migrate to the GPU-server in future

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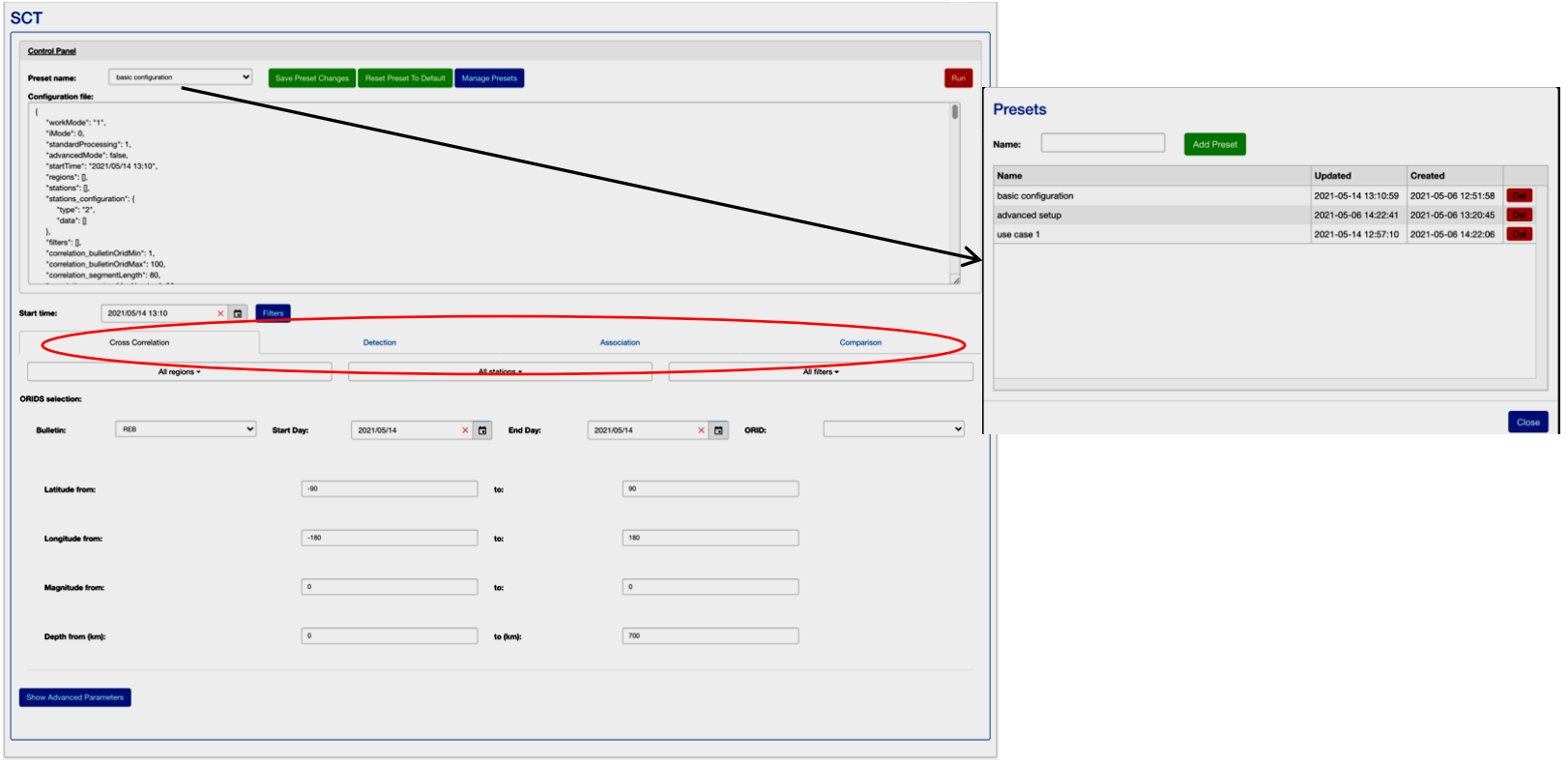
CONTROL PANELS, SPOT, EVENTS, PRESETS



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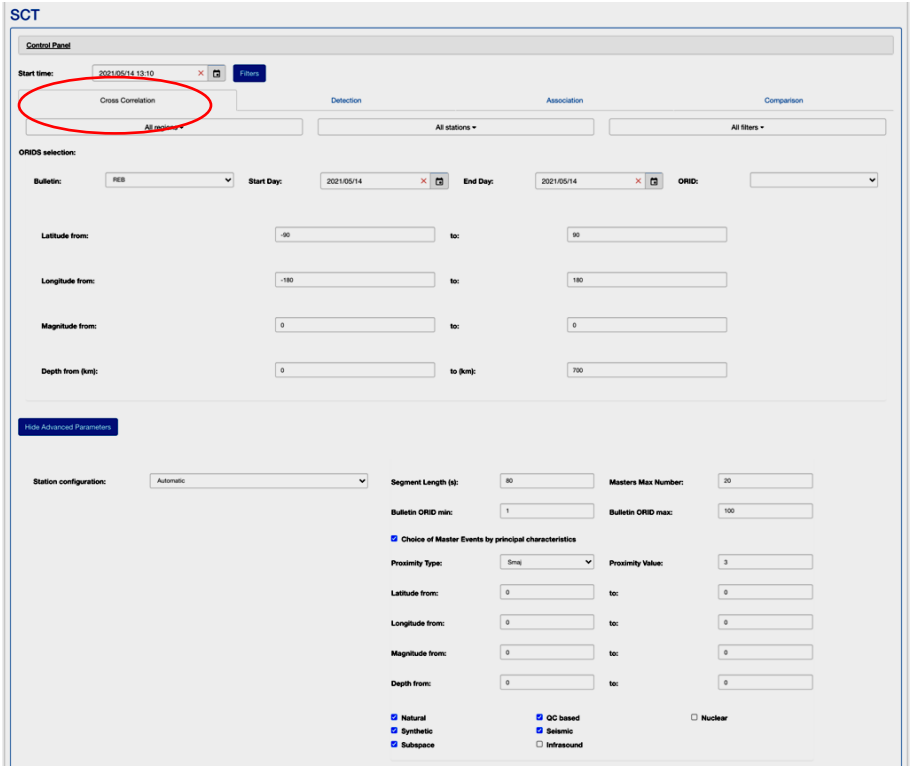
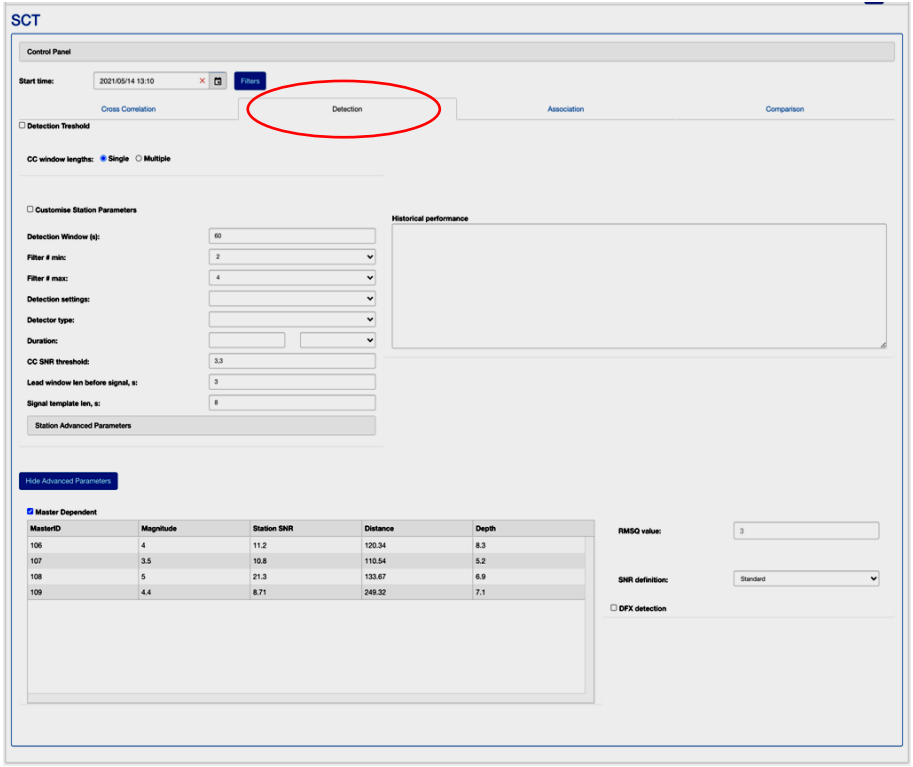
CONTROL PANELS: CC, DETECTION





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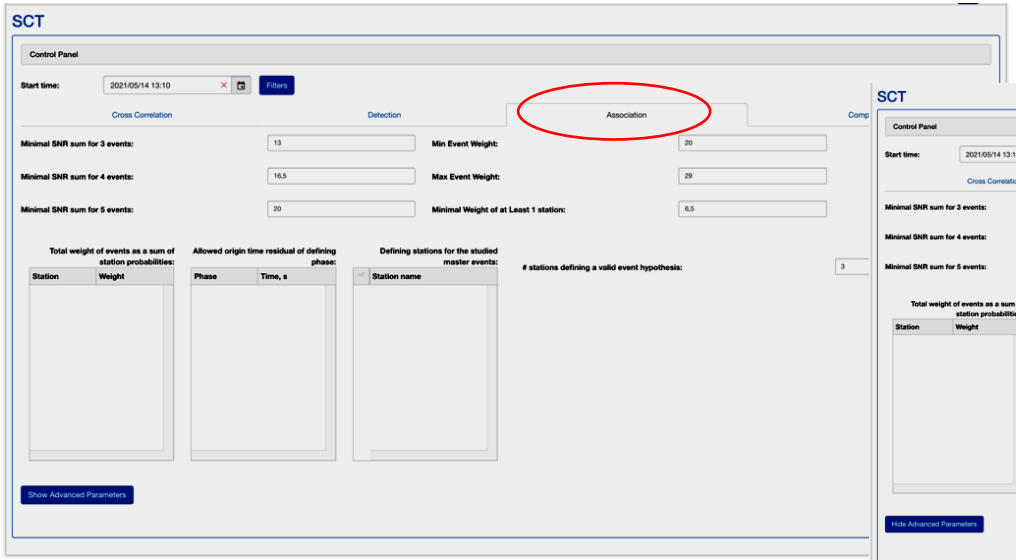
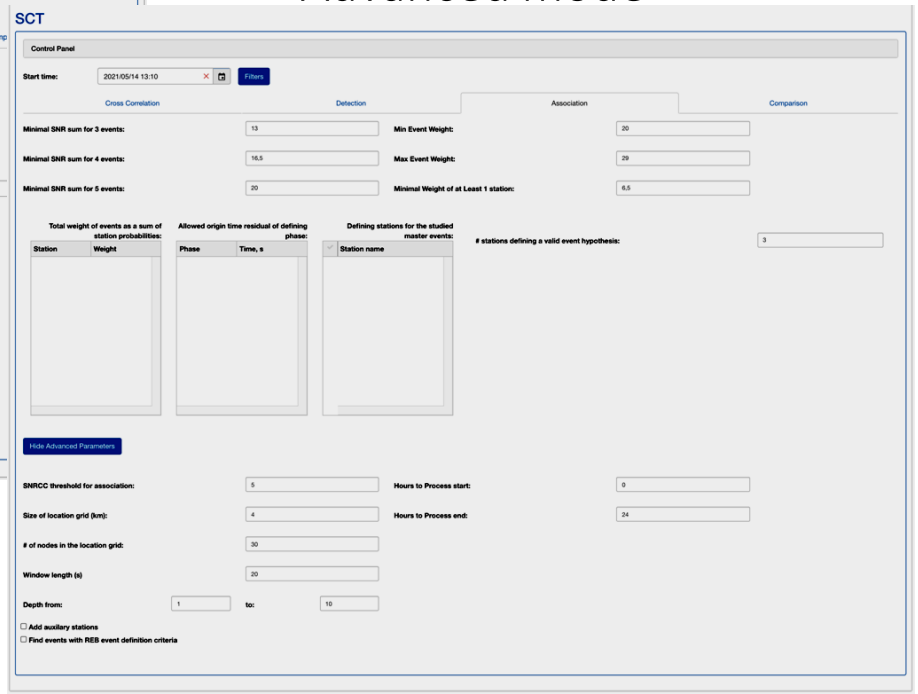
CONTROL PANELS: ASSOCIATION

Basic mode



Advanced mode



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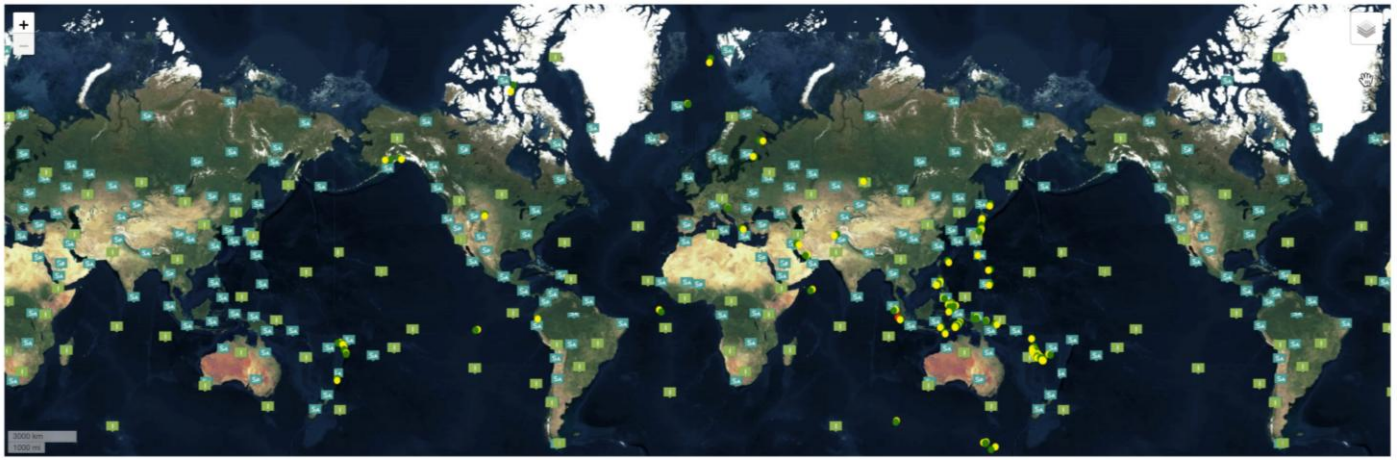
MAP: STATIONS AND EVENTS



Refresh map

#	ORID	Time	St Dev	Latitude	Longitude	Depth	MB	Nass	New/Reb	REB Orid	Match
	>= <=		>= <=	>= <=	>= <=	>= <=	>= <=	>= <=		>= <=	>= <=
1	13985426	0:16:2.40	0.08	-21.521	170.011	205.5	3.74	5	SEL	20103084	5
2	6816836	0:30:16.70	1.18	3.415	126.15	45.1	4.07	13	SEL	20103088	7
3	7079105	0:37:21.21	1.58	-22.273	171.754	116.7	4.46	14	SEL	20089809	10
4	6651558	1:6:52.76	1.72	-2.671	139.629	45.2	4.22	9	SEL	20089651	4
5	9604969	1:16:33.82	2.09	-20.624	175.43	51.4	3.98	6	REB	20102769	3
6	15672297	1:25:1.39	0.69	2.798	127.879	62.2	3.73	4	SEL	20089621	3
7	8458423	1:50:9.92	1.37	-21.762	171.071	0	4.63	6	REB	20103073	4
8	12186108	2:37:20.11	1.12	-21.534	171.269	133.2	4.11	8	SEL	20101809	6
9	16438469	2:46:22.62	1.41	46.566	146.253	373.7	3.07	8	REB	20103227	5
10	9168788	2:52:24.84	1.45	38.4	142.012	52.3	3.53	11	SEL	20103180	5

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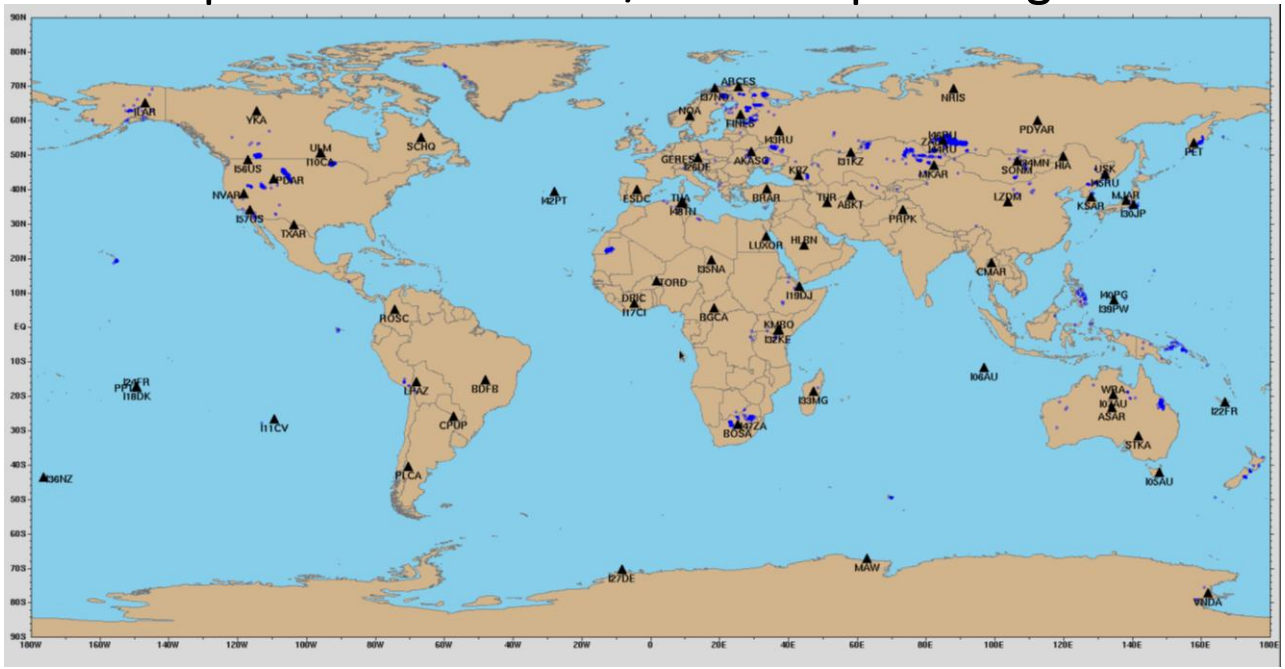
Spot Check with seismic/infrasound processing



See Poster No.P2.3-356 for more details

REB events with associated infrasound signals detected at infrasound IMS stations are shown by blue circles. Most active mines are located in Eurasia, North America, Africa, and Australia. Total number of events for a given mine is from ~10 to ~8,000. Infrasound stations are from ~100 km to ~2,000 km. There are many REB events with 1 seismic and 2 infrasound phases associated. Infrasound waveform templates are processed as for seismic arrays. Historical data are used to tune processing: template length, frequency bands, detection thresholds, origin time residuals, etc.

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CONCLUSION

- Given 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 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 matched filter detector (based on waveform cross correlation) provides higher sensitivity and resolution with a competitive false alert rate

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