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PREPARATORY COMMISSION

COMPREHENSIVE
NUCLEAR-TEST-BAN
TREATY ORGANIZATION

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CTBTO, IDC/SA/SM

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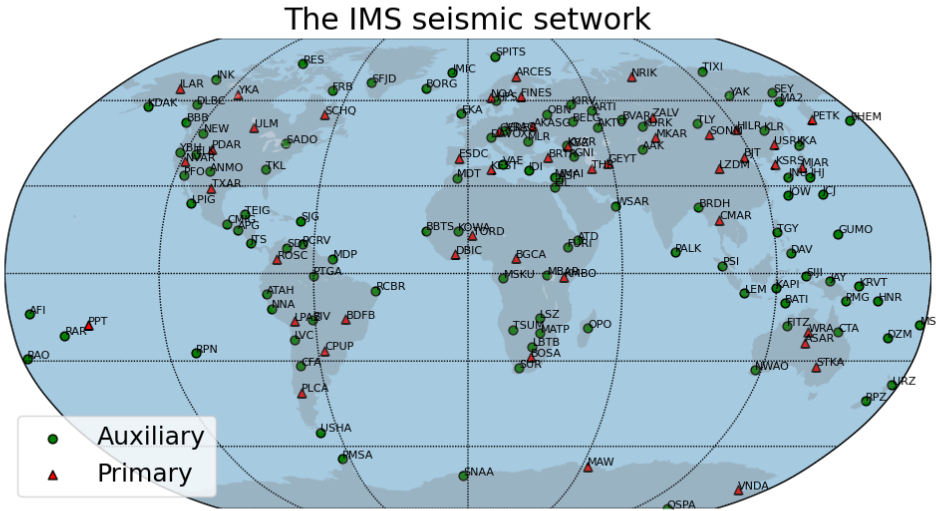
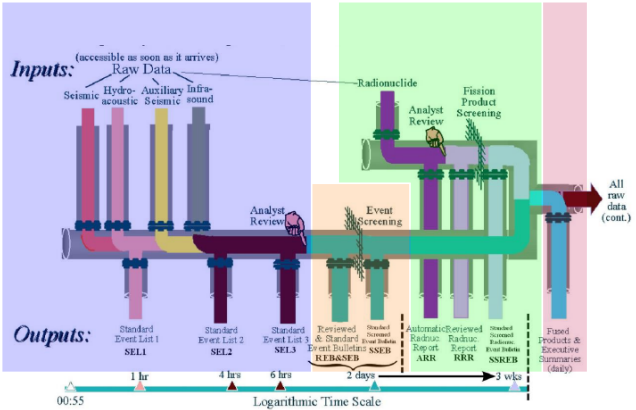
Outline

Outline

The IMS seismic networks

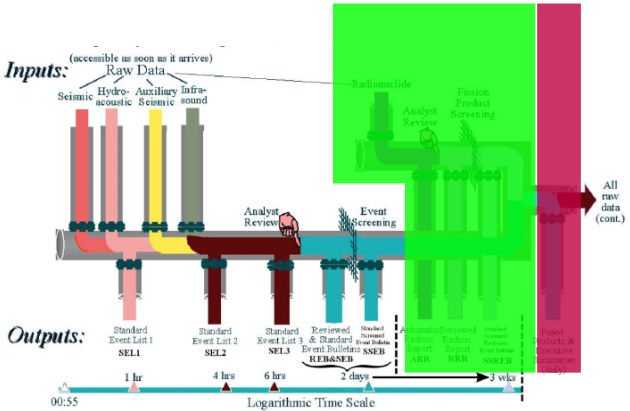


The IDC processing pipeline



- SHI (Seismic/Hydroacoustic/Infrasonic) processing:
  - Automatic processing
  - Interactive processing
- Radionuclide processing
- Technology fusion

The IDC processing pipeline



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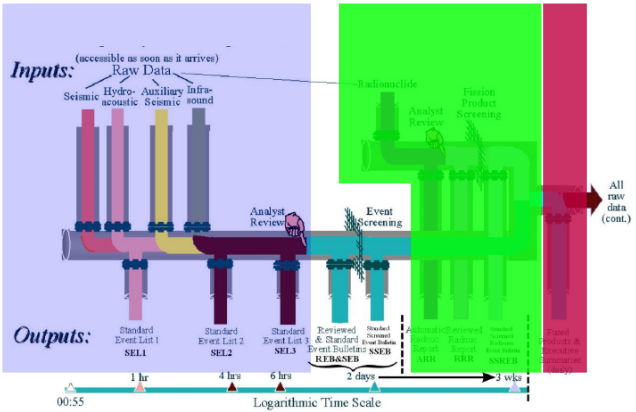
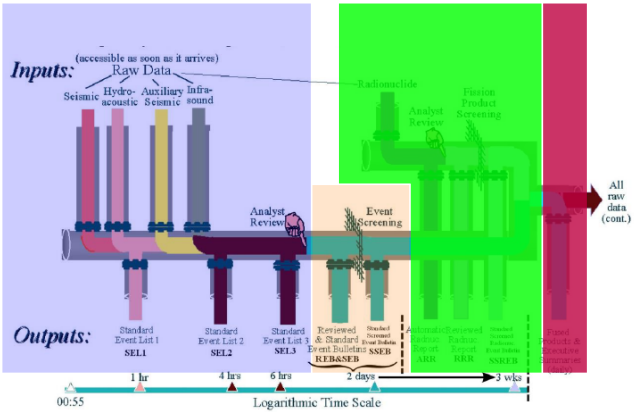


- SHI (Seismic/Hydroacoustic/Infrasonic) processing:
  - Automatic: Standard Event Lists (SEL1, SEL2, SEL3) are generated



- SHI (Seismic/Hydroacoustic/Infrasonic) processing:
  - Automatic: Standard Event Lists (SEL1, SEL2, SEL3) are generated
  - Interactive: analysts review the SELx's; generated Event Bulletins: Reviewed (REB), Standard Screened (SSEB),...

Interactive processing

During interactive processing, analysts:

- delete, split, merge and create new events;
- edit events:
  - add phases;
  - retime (shift) phases;
  - rename phases;
  - correct mis-associations, locations, depths;
  - ...
- and many more...

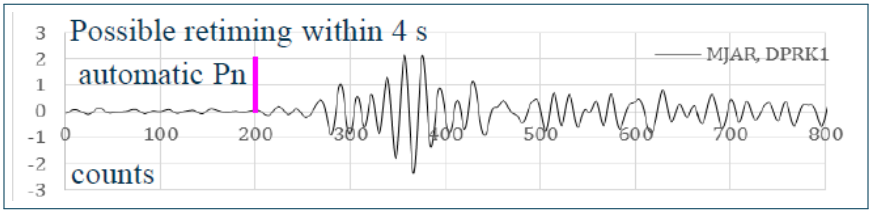
Station tuning: an ongoing effort with the following objectives:

- Assess performance of IMS stations:
  - Associated phases rate;
  - (Manually) added arrival rate;
- Tune defining parameters for the IMS stations:
  - Detection thresholds;
  - ...
- Define optimal monitoring performance.

Outline

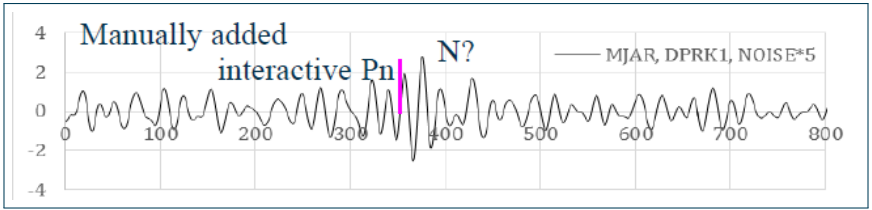
Automatic vs interactive arrival picking

If the arrival is clear (e.g. the SNR is high), then the automatically picked arrival time is not changed during interactive analysis.



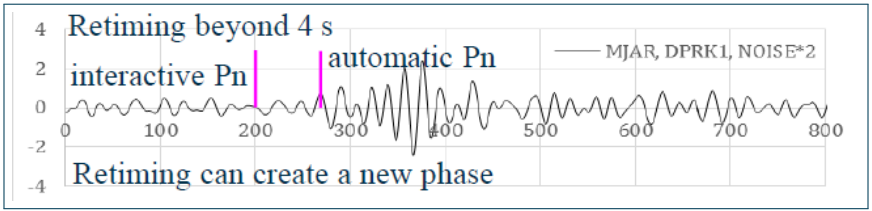
Automatic vs interactive arrival picking

The analysts can also **add** arrivals that were not detected by the automatic detector.



Automatic vs interactive arrival picking

Analysts may also shift (**retime**) an automatically picked arrival to another (usually earlier) time.



Retimed vs added arrivals

The analysts are not allowed to shift an arrival beyond a certain point (*retiming maximum interval*);

If the two arrivals differ that much in time, a new arrival should be *added* and the previous one removed;

Hence, it may happen that a manually *added* arrival is actually just a *retimed* (shifted) arrival;

Adding new arrivals affects performance metrics;

The *retiming maximum interval*, if too small, artificially deteriorates performance metrics;

The *maximum retiming limit* was until Dec 2018 set to ± 4 sec.

Regular phases: Detections that have been assigned a specific phase type (e.g. P, S, etc.) by the automatic detector.

N phases: Detections that were not assigned a specific phase type.

- they are **not** noise;
- an N phase may converted to a regular phase by an analyst.

Analysts may rename N phases to regular phases and regular phases to other regular phases!

Association rate: percentage of (automatic) detections associated by the analysts to events.

Can be defined in two ways:

- using only regular phases or
- using both regular and N phases

Is equivalent to precision $= 1 -$ false discovery rate;

Must be $\geq 10\%$

Added (missed) rate: percentage of the detections associated by analysts that were missed by the automatic detector.

Can be defined in two ways:

- using only regular phases or
- using both regular and N phases (✓)

Is equivalent to miss rate;

Must be $\leq 20\%$

Performance metrics

The association and manually-added rate depend greatly on the number of detections of the detection algorithm;

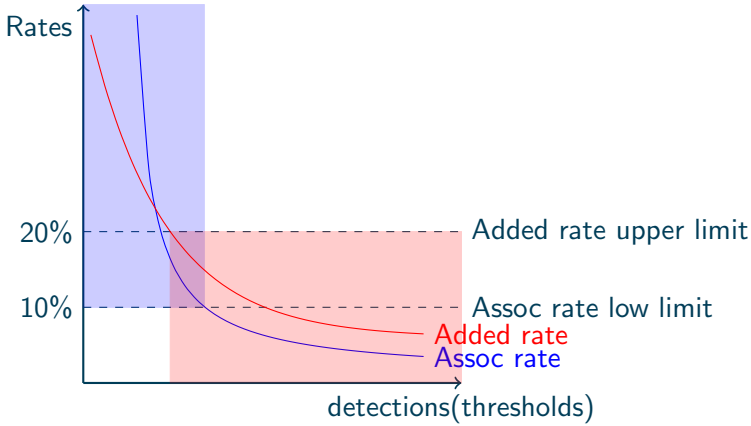
The detection algorithm depends on the threshold values of the STA/LTA detector (the thresholds depend on slowness, frequency and azimuth);

- low thresholds $\Rightarrow$ many detections $\Rightarrow$ low added (miss) rate and low association rate (=high false detection rate);
- high thresholds $\Rightarrow$ few detections $\Rightarrow$ high added (miss) rate and high association rate (=low false discovery rate).

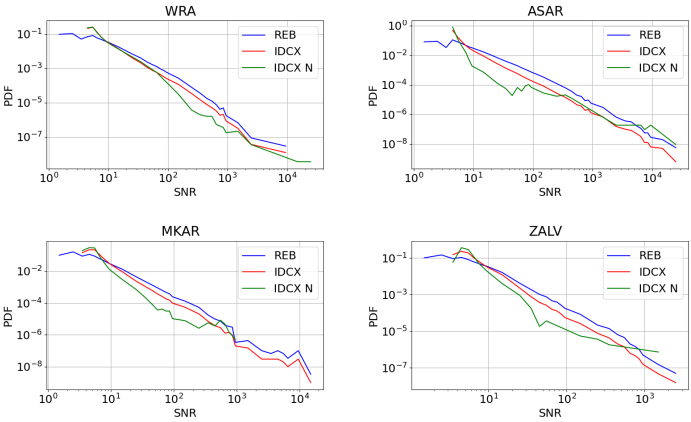
Optimization of both the association and manually-added rates is self-contradicting, but

- it is essential that the miss rate is as low as possible since no nuclear explosion should go unnoticed by the IMS;
- a high false-discovery rate compromises the quality of the automatic event lists and adds workload to the analysts.

Performance metrics



Detections vs SNR (2018)



IDCX: Automatic detections (regular phases);

IDCX N: Automatic detections (N phases);

REB: Detections that made it to the reviewed bulletin.

Detections vs SNR (2018)

WRA, ASAR, MKAR and ZALV are the most prolific stations in the primary seismological IMS network;

- Number of detections decreases logarithmically with SNR;
- Thresholds can be inferred by the lowest SNR for which there exist automatic detections;
- Most detections in the REB have SNR below the threshold; these are all added phases. *Added* detections can be:
  - actual new phases or
  - retimed phases beyond the *retiming maximum interval*.

All added arrivals are work for the analysts.

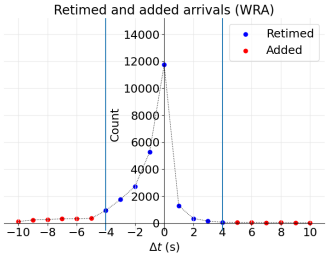
Retimed and added arrivals

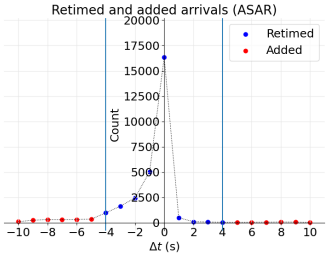
The next two slides show arrivals in the REB vs how much they were retimed, Δt.

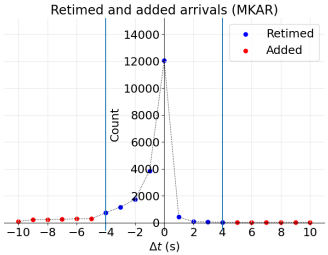
- number of arrivals vs Δt (see plots );
- SNR of arrivals vs Δt (see plots );

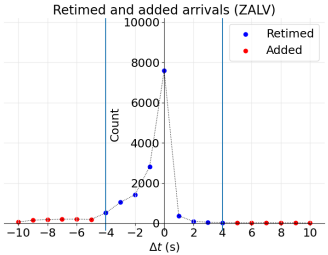
- Blue denotes arrivals that were simply retimed (shifted within ± 4 sec);
- Red denotes arrivals that had to be shifted beyond ± 4, they were therefore added as new arrivals;
- Added arrivals:
  - are not a lot but are that many (see plots ), but add a lot of work to analysts;
  - have SNR's below the prespecified detection thresholds (see plots ).

Retimed and added arrivals

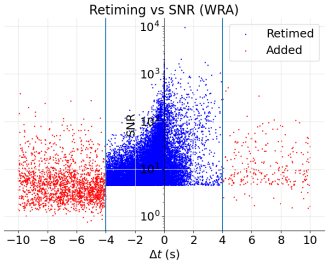


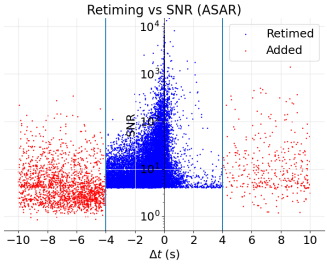


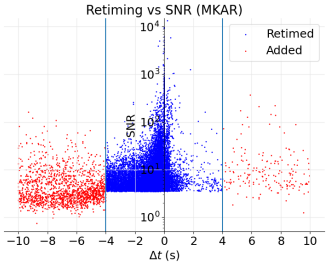


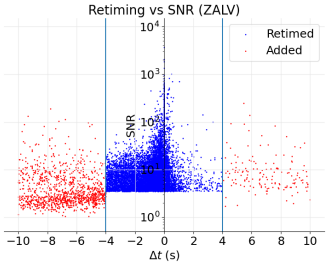


SNR vs Retiming









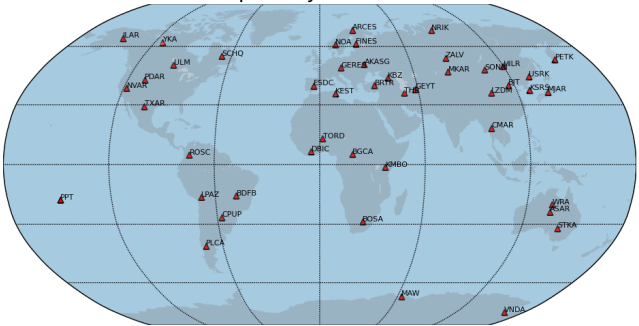
Outline

Experiment design

- The *retiming maximum interval* was modified from 4 sec to 10 sec on Dec 5th, 2018.
- 1 year of data were recorded (to allow for seasonal variations and sufficient statistics)
  - 2017/12/5 – 2018/12/4 (essentially 2018)
  - 2018/12/6 – 2019/12/5 (essentially 2019)

- In this presentation, we study only primary stations:

The IMS primary seismic setwork



- Mostly interested in the 15 most prolific stations (they contribute the most to events);
- Some detailed results for the 4 most prolific stations.

Most prolific stations 1/2

	2018				2019		
	sta	events	%		sta	events	%
1.	WRA	24960	69.10	1.	WRA	24905	70.49
2.	ASAR	24514	67.87	2.	ASAR	24796	70.18
3.	MKAR	24115	66.76	3.	MKAR	24145	68.34
4.	ZALV	15501	42.91	4.	ZALV	14687	41.57
5.	ILAR	14962	41.42	5.	ILAR	13765	38.96
6.	SONM	12941	35.83	6.	SONM	12530	35.47
7.	FINES	12088	33.47	7.	FINES	12517	35.43
8.	TORD	11247	31.14	8.	CMAR	11222	31.76
9.	CMAR	11245	31.13	9.	STKA	9563	27.07

Most prolific stations 2/2

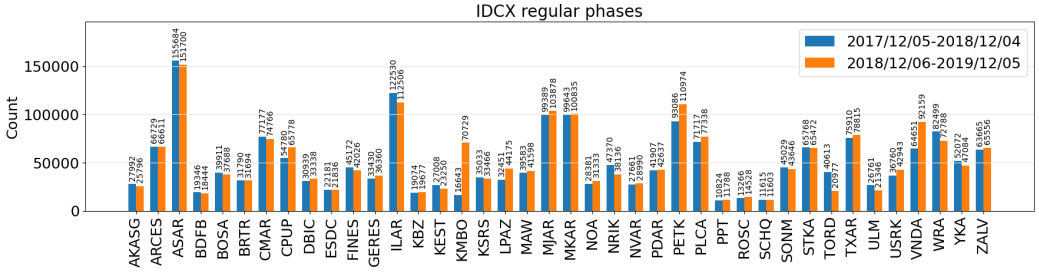
2018				2019			
	sta	events	%		sta	events	%
10.	TXAR	9741	26.97	10.	TXAR	9483	26.84
11.	STKA	9696	26.84	11.	ARCES	9043	25.60
12.	YKA	9377	25.96	12.	YKA	8760	24.79
13.	NVAR	9239	25.58	13.	BRTR	8594	24.32
14.	PDAR	8658	23.97	14.	AKASG	8168	23.12
15.	ARCES	8638	23.91	15.	PDAR	8062	22.82
	⋮				⋮		
17.	BRTR	8658	23.51	19.	NVAR	8168	22.17
18.	AKASG	8638	22.47	21.	TORD	8062	19.99

Remarks on ‘most prolific’ stations

- 13 out of 15 stations common in the Top-15 list of prolific stations
- TORD and NVAR made the Top-15 prolific stations in 2018 but not in 2019
- BRTR and AKASG made the Top-15 prolific stations in 2019 but not in 2018

TORD: very unstable (many off-days) in 2019
NVAR: $-1,000$ detections in 2019; rank is about the same
AKASG: -500 detections in 2019; rank is about the same
BRTR: no change in no. of detections; the rank changed somewhat

Detections per station do not differ significantly between 2018 and 2019



Primary stations with big variance

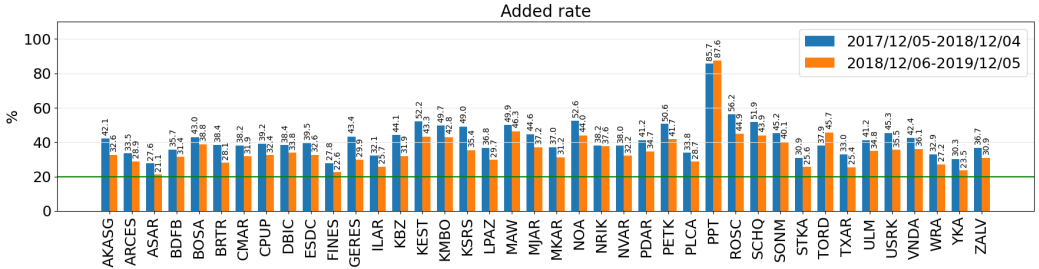
	2018				2019		
	sta	events	%		sta	events	%
8.	TORD	11247	31.14	21.	TORD	7063	19.99
25.	PETK	7277	20.60	26.	PETK	5980	16.55
30.	VNDA	5240	14.83	49.	VNDA	3410	9.44

TORD: was very unstable (many off-days) in 2019

PETK: not in the top-15; to be examined, nevertheless

VNDA: not in the top-15; to be examined, nevertheless

Added rate for all primary stations



- ✓ in general decreased by 5–8% (that's 10–30% less workload!)
- ✗ in some cases (PPT, TORD) it increased (PPT is not very prolific anyway, it contributes to only 6-8%)
- ✗ still over the threshold 20%

Rough calculation of analyst workload

WRA:

Added rate in 2018: 32.9%

Added rate in 2019: 27.2%

Workload: $\frac{27.2-32.9}{32.9} = -17.3\%$

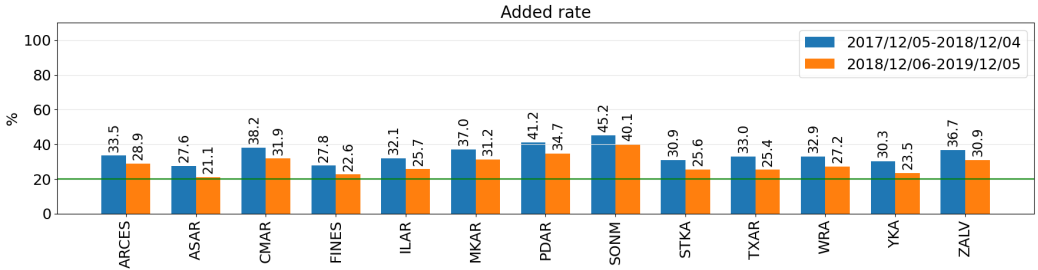
ASAR: Workload: $\frac{21.1-27.7}{27.7} = -23.8\%$

MKAR: Workload: $\frac{31.2-37.0}{43.4} = -15.7\%$

ZALV: Workload: $\frac{30.9-36.7}{36.7} = -15.8\%$

GERES: Workload: $\frac{29.9-43.4}{43.4} = -31.1\%$

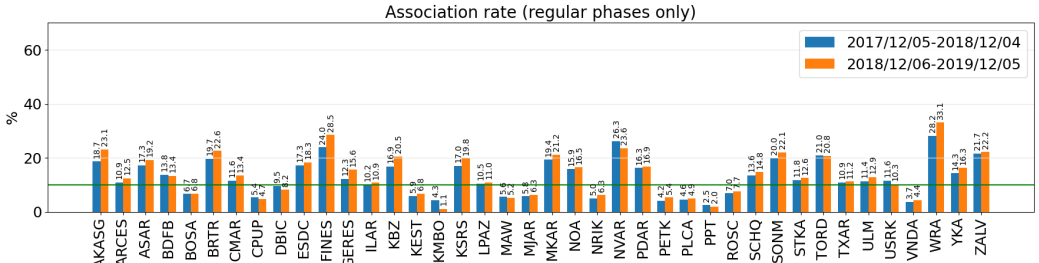
Added rate for highest contributors



✓ decreased by 5–8% (that's 10–30% less workload!)

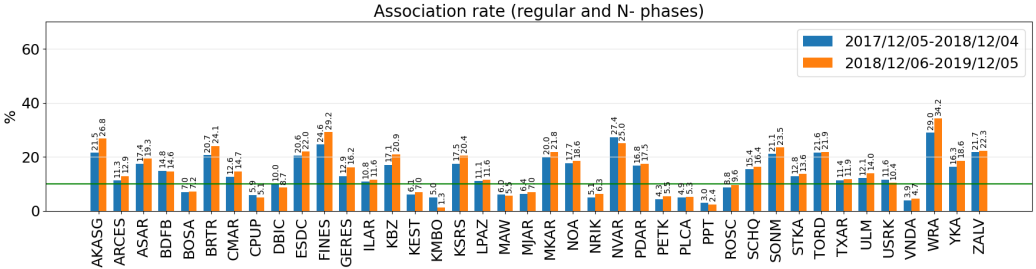
✗ still over the threshold 20%

Assoc rate (regular phases)



- ✓ in general increased by up to 4% (that's up to 15% less workload!)
- ✗ in some cases it decreased (BOFB, CPUP, DBIC, KMBO, MAW, PPT, USRK)
- ✓ in most cases over 10%

Assoc rate (regular + N phases)



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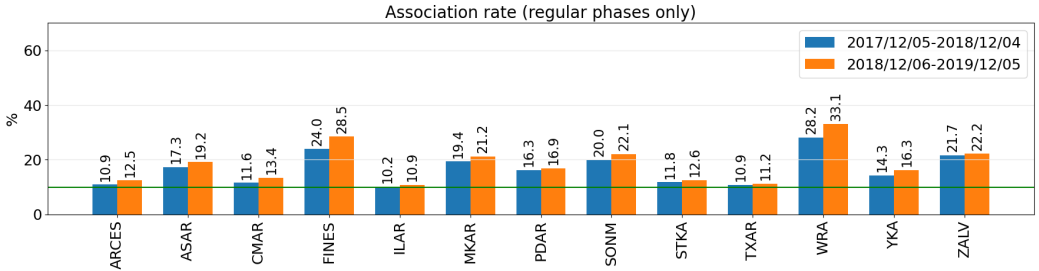
Stations with increased assoc rates

2018				2019			
	sta	events	%		sta	events	%
21.	USRK	6057	16.77	23.	USRK	5446	15.41
28.	DBIC	3807	10.54	29.	CPUP	3509	9.93
29.	CPUP	3788	10.49	31.	MAW	3295	9.33
31.	MAW	3667	10.15	32.	DBIC	3237	9.16
34.	BDFB	3380	9.36	34.	BDFB	2955	8.36
39.	PPT	2091	5.79	38.	PPT	2127	6.02
41.	KMBO	1198	3.32	40.	KMBO	1175	3.33

Fortunately not highly contributing

Assoc rate (regular phases)



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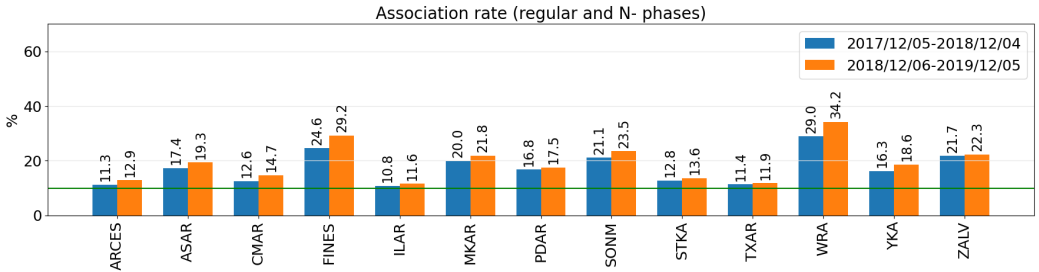
- ✓ in all cases over 10%

Assoc rate (regular + N phases)



- ✓ in general increased by up to 4% (that's up to 15% less workload!)
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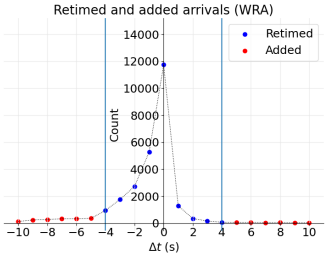
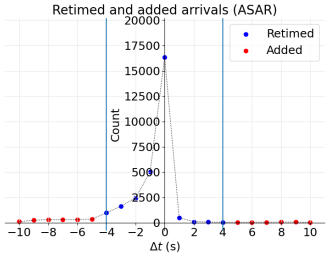
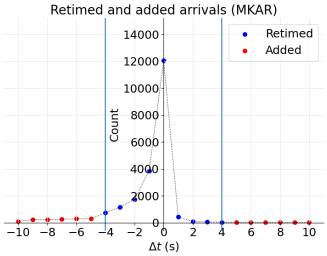
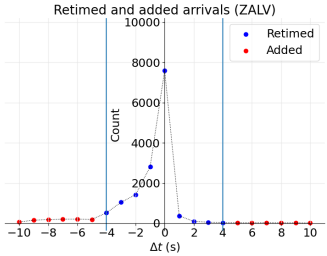
Retimed and added arrivals (2018)









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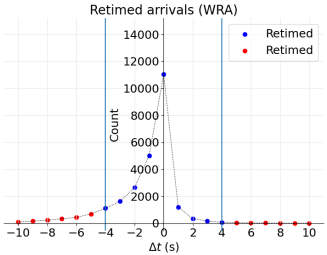
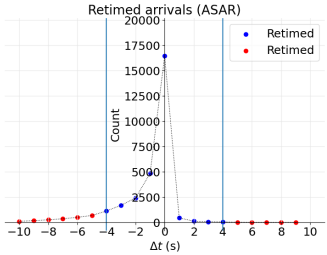
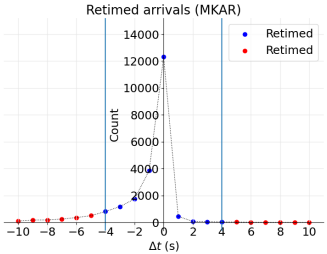
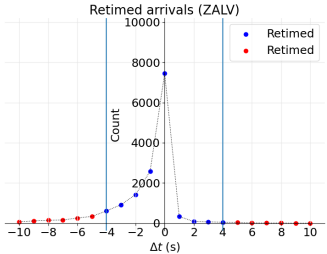
Retimed arrivals only (2019)









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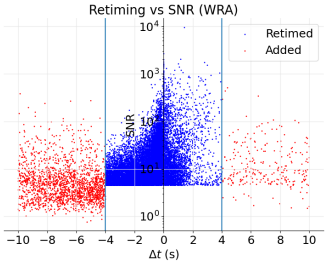
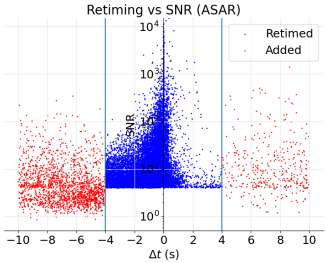
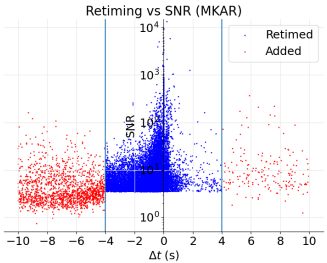
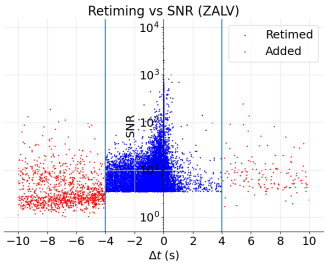
SNR vs Retiming (2018)









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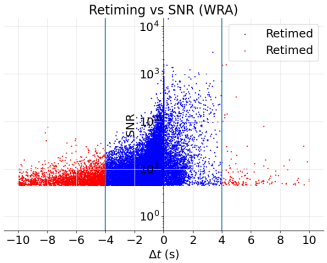
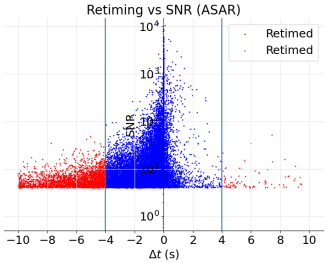
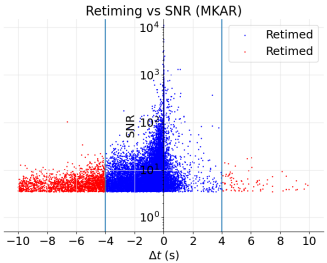
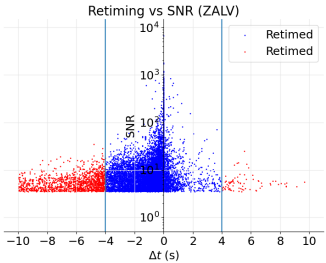
SNR vs Retiming (2019)









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Conclusions

- Added rate (must be $\leq 20\%$)
  - ✓ in general decreased by 5–8%;
  - ✓ in general analyst workload decreased by 10–30%;
  - – in some cases it increased, but did not affect performance significantly.
  - ✗ still over 20%
- Association rate (must be $\geq 10\%$)
  - ✓ in general increased by up to 4%;
  - ✓ analyst workload decreased by up to 15%;
  - – in some cases it decreased, but did not affect performance significantly.
  - ✓ in most cases over 10%

Next steps

- Examine stations that showed unexpected behavior;
- Study the effect on more primary and prolific auxiliary stations;

- Threshold optimization for most prolific stations;
  It is expected to increase mainly the assoc rate and secondly the added rate;

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