SnT 2021
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Tuning the IMS seismic stations by optimization of their detection thresholds

Christos Saragiotis and Ivan Kitov
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POSTER

P4.1-455

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ABSTRACT

Two principal performance measures of the International Monitoring System (IMS) stations detection capability are the rate of automatic detections associated with events in the Reviewed Event Bulletin (REB) or precision of the REB and the rate of detections manually added to the REB or miss rate of the REB.

These two metrics are significantly influenced by prespecified slowness-, frequency- and azimuth- dependent detection thresholds used in the short-term average over long-term average ratio detection scheme of the IMS stations.

The thresholds should be set at optimal values that a) the miss rate is as low as possible since no nuclear explosion should go unnoticed by the IMS and b) the precision is as high as possible as low precision compromises the quality of the automatically generated event lists and adds heavy and unnecessary workload to the seismic analysts during the interactive processing stage.

In this abstract we present two procedures followed for optimizing the STA/LTA detection thresholds:

- The method described in the SHI processing manual and
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- The method described in the SHI processing manual and
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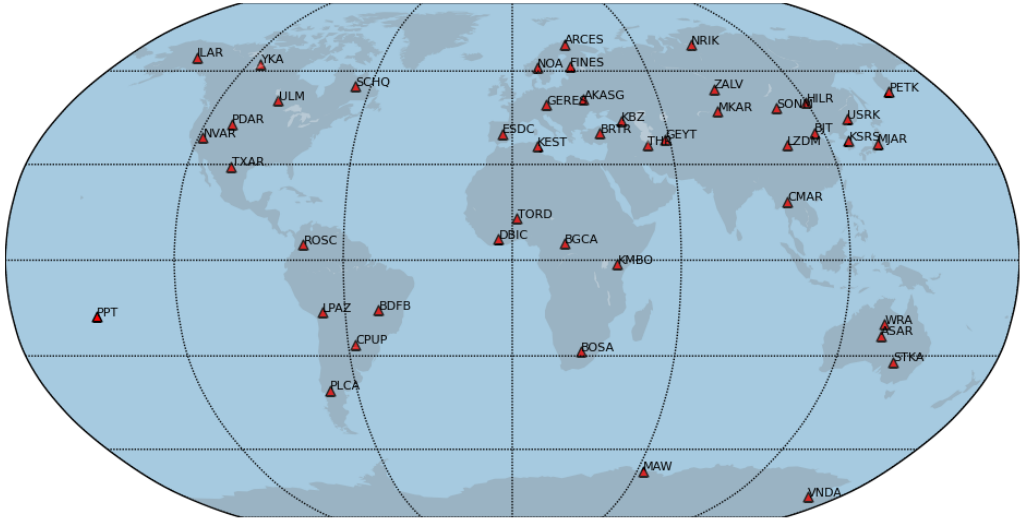
The **IMS primary seismic network** is a sparse global seismological network that currently consists of 44 seismic stations (27 arrays, 17 3-C single stations).



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The signal detection algorithm is then applied to every beam and a detection is declared for the beam with the highest STA/LTA ratio, provided that this ratio exceeds a prespecified threshold (**beam SNR** or **beam threshold**).

```
#!BeginTable beam-recipe
|name     |type|rot |std|snr  |azi   |slow  |phase    |flo  |fhi  |ford|zp|ftype|group   |
 FI_01     coh  no   0   4.00    0.0  0.0000 -         0.75  2.25  3    0  BP    a1-c
 FI_02     coh  no   0   4.00    0.0  0.0952 -         0.75  2.25  3    0  BP    a1-c
 FI_03     coh  no   0   4.00   60.0  0.0952 -         0.75  2.25  3    0  BP    a1-c
 FI_04     coh  no   0   4.00  120.0  0.0952 -         0.75  2.25  3    0  BP    a1-c
 FI_05     coh  no   0   4.00  180.0  0.0952 -         0.75  2.25  3    0  BP    a1-c
 FI_06     coh  no   0   4.00  240.0  0.0952 -         0.75  2.25  3    0  BP    a1-c
 FI_07     coh  no   0   4.00  300.0  0.0952 -         0.75  2.25  3    0  BP    a1-c
 FI_08     coh  no   0   4.70    0.0  0.3334 -         0.75  2.25  3    0  BP    a1-c
 FI_09     coh  no   0   4.70   30.0  0.3334 -         0.75  2.25  3    0  BP    a1-c
 FI_10     coh  no   0   4.70   60.0  0.3334 -         0.75  2.25  3    0  BP    a1-c
 FI_11     coh  no   0   4.70   90.0  0.3334 -         0.75  2.25  3    0  BP    a1-c
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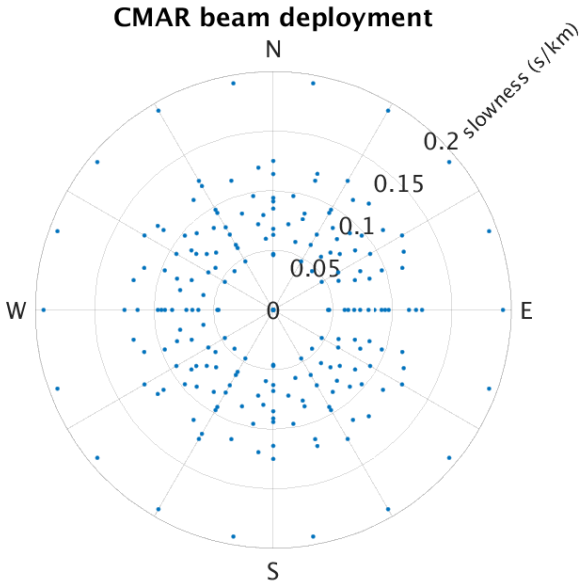

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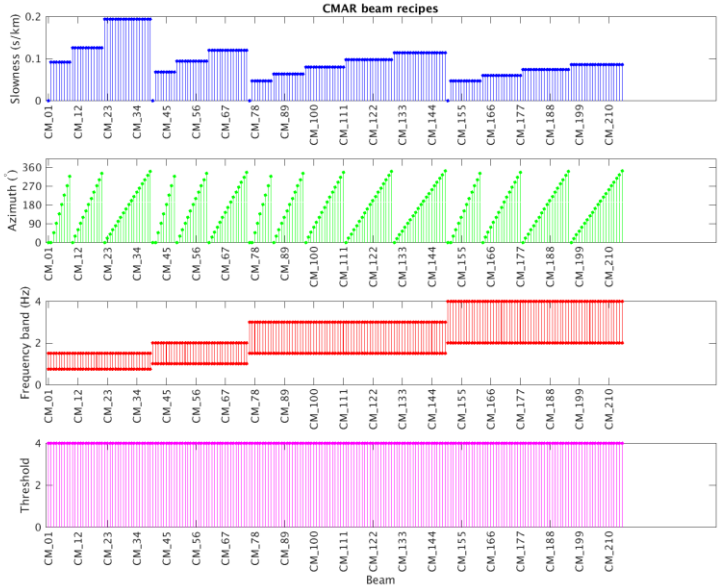

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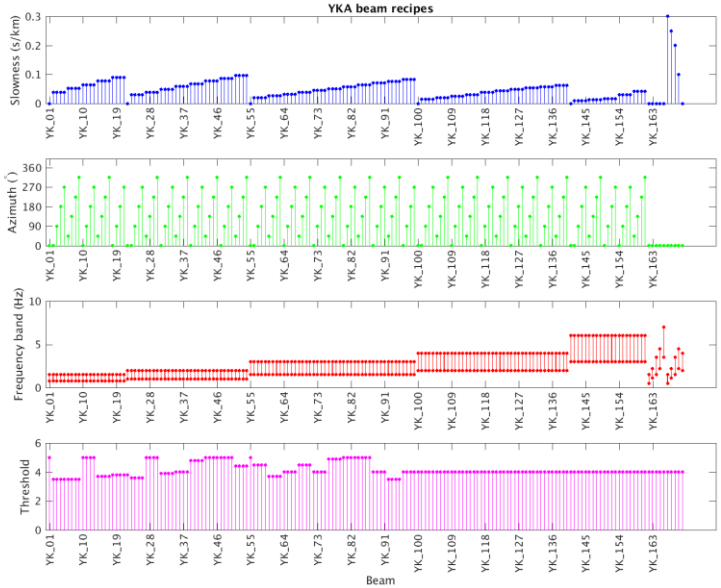

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- The **association rate:** ratio of automatically picked arrivals that after analysts' review are associated to an event over all the automatically detected arrivals
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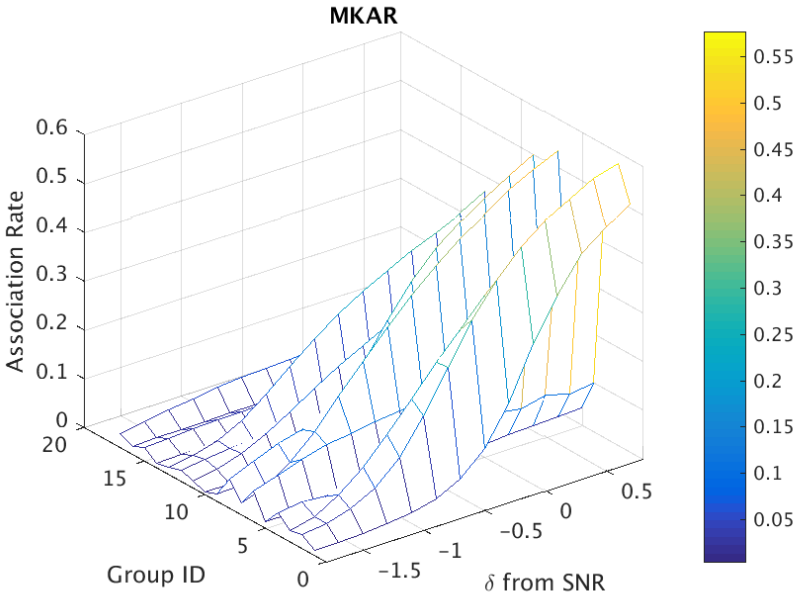

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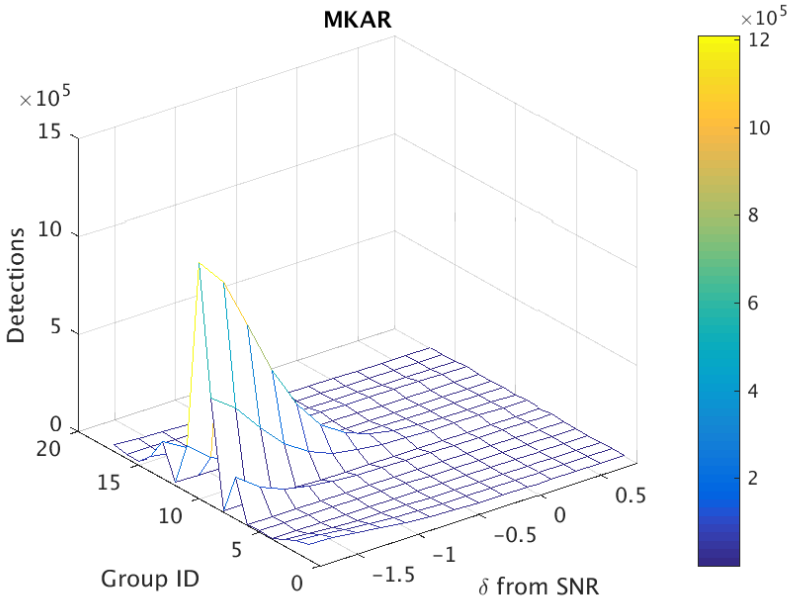

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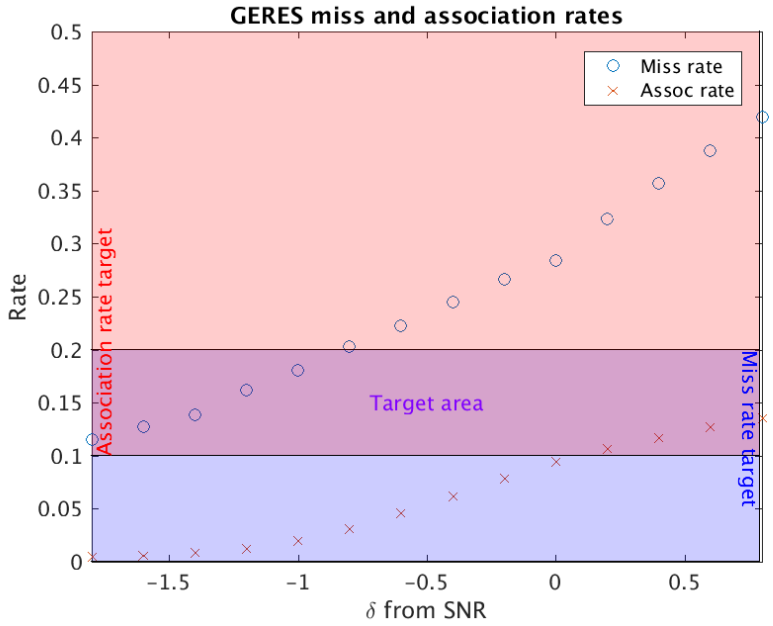
These two metrics largely depend on the **beam thresholds** and this dependence creates a conflict

- **High detection beam thresholds** result in few detections and hence a) high association rate (very few false detections) and also b) high miss rate (many phases go undetected)
- **Low detection beam thresholds** result in many detections and hence a) in low miss rate but also b) low association rate (many false detections)



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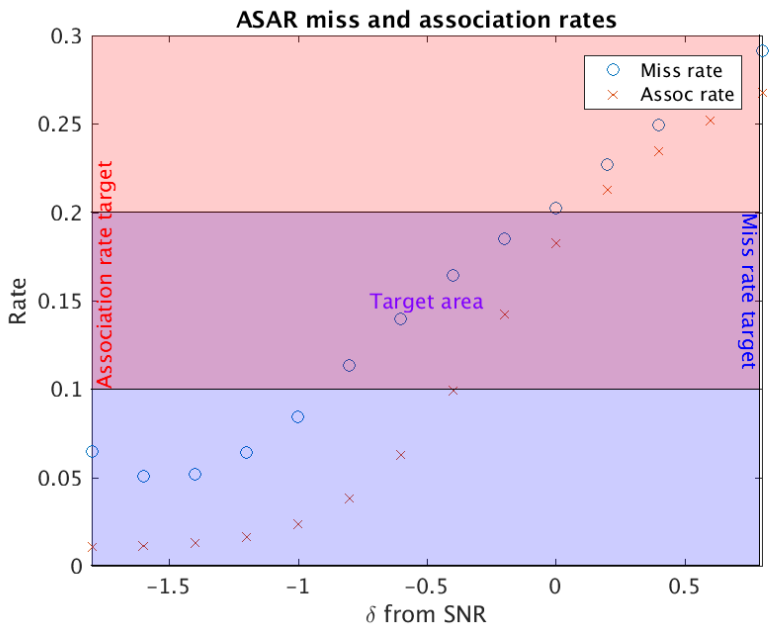

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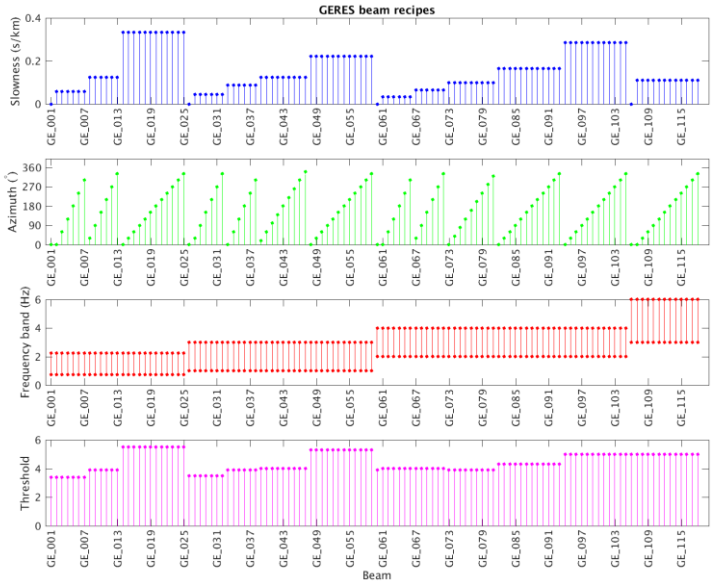

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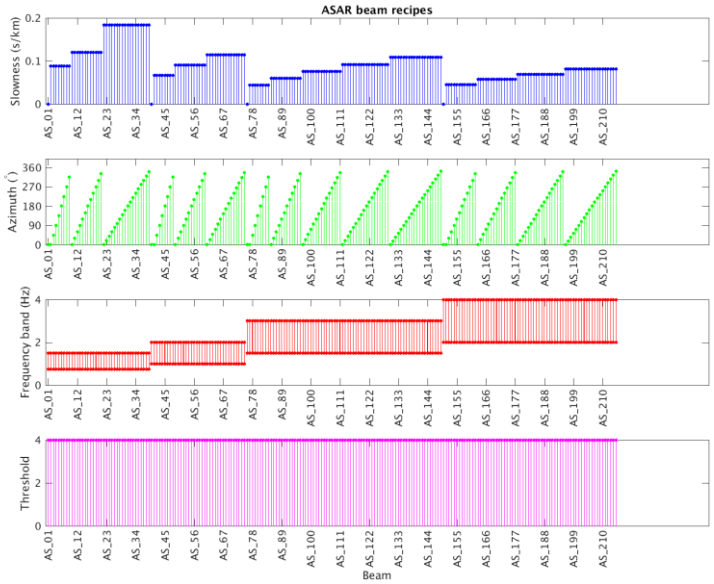

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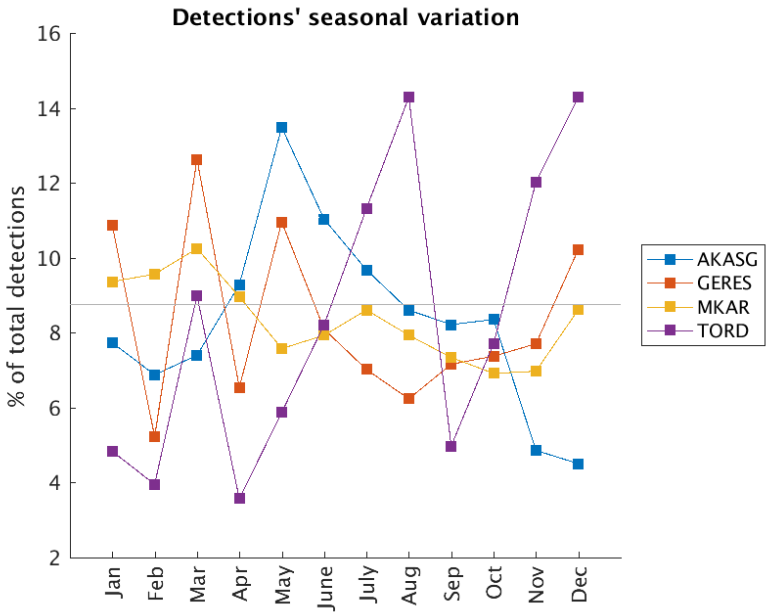

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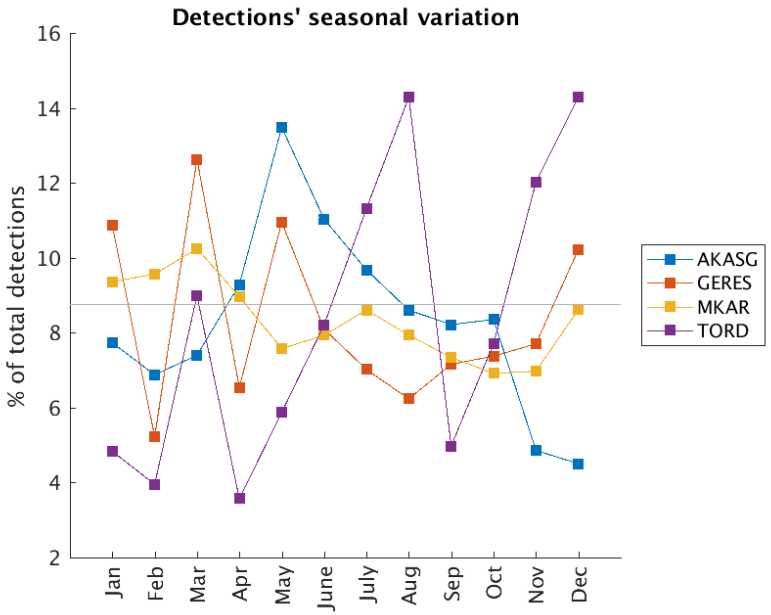
Practical limitations

- It is **impossible to test all** combinations of many different beam thresholds; assuming even only 10 beam groups and 10 different threshold levels gives 10^{10} possible combinations
- Optimizing one beam group threshold affects the value of the other beam groups (**channel jumping**)
- Only the automatic system can be checked (**analyst involvement is resource-intensive beyond capacity**)
- The current thresholds (starting point) of most stations do not yield rates close to the target rates.



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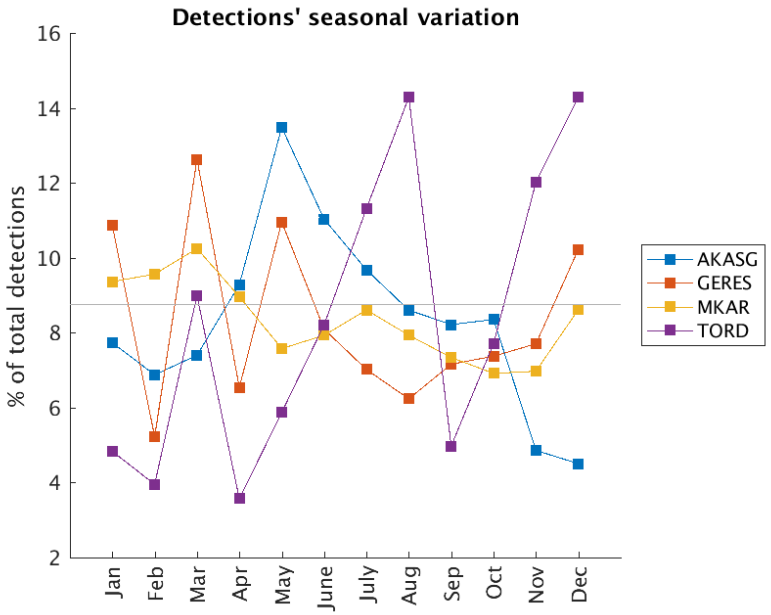

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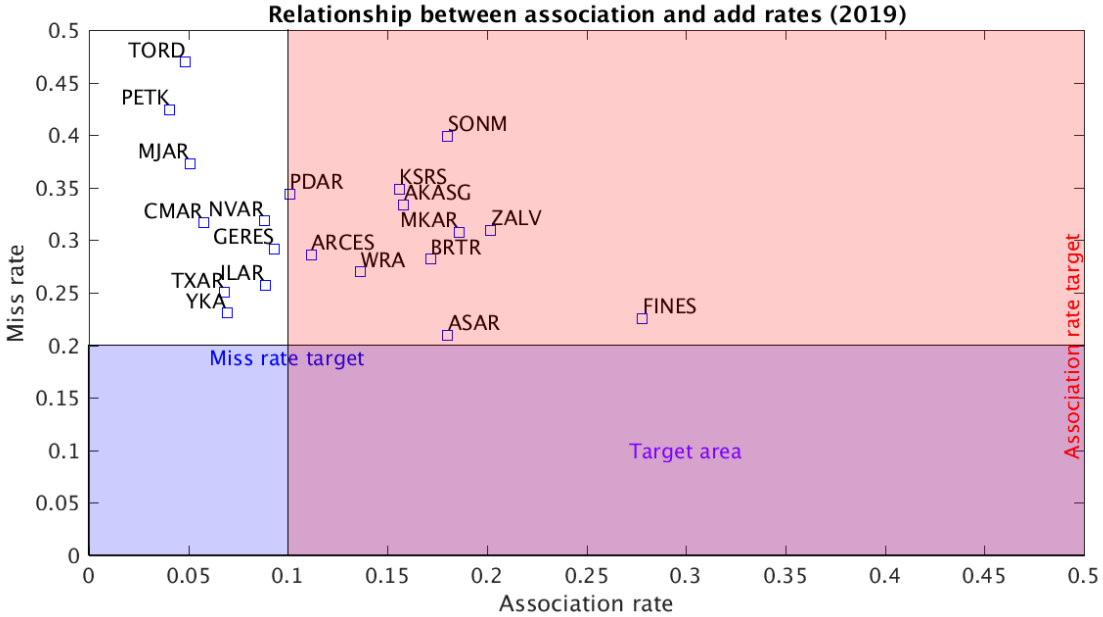

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Optimization procedure described in the SHI processing manual

1) Run the DFX application using **a STA/LTA threshold of 3.0** for all channels on **"control" data** that have been reviewed by analysts.
2) Determine the relationships between the number and SNR of detections for each channel.
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4) Determine the relationships between the number and SNR of added (missed) phases for each channel.
5) Set an objective for the association rate for all channels (e.g., 10%).
6) If the existing STA/LTA threshold for beams within a beam group has association rate less than the objective, **increase** the thresholds until the objective is achieved.
   If the existing STA/LTA threshold for beams within a beam group has association rate that is higher than the objective, **decrease** the thresholds until the objective is achieved (or the percentage of added phases becomes zero).
7) Repeat step 6 until a relationship between the association rate and the added rate is obtained.
8) Choose a point where the added rate is lower than a given percentage, say 20% (first priority) and the association rate is a set percentage, say 10%, (second priority).
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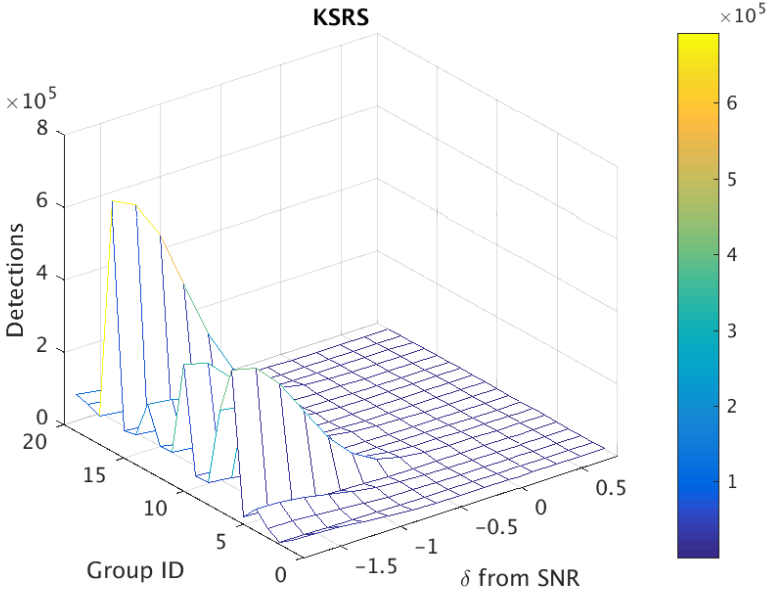

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Tuning the IMS seismic stations by optimization of their detection thresholds

Christos Saragiotis and Ivan Kitov, CTBTO, IDC/SA/SM

CTBTO PREPARATORY COMMISSION

METHODS

Optimization procedure described in the SHI processing manual

1) Run the DFX application using **a STA/LTA threshold of 3.0** for all channels on **"control" data** that have been reviewed by analysts.
2) Determine the relationships between the number and SNR of detections for each channel.
3) Determine the relationships between the number and SNR of associated phases for each channel.
4) Determine the relationships between the number and SNR of added (missed) phases for each channel.
5) Set an objective for the association rate for all channels (e.g., 10%).
6) If the existing STA/LTA threshold for beams within a beam group has association rate less than the objective, **increase** the thresholds until the objective is achieved.
   If the existing STA/LTA threshold for beams within a beam group has association rate that is higher than the objective, **decrease** the thresholds until the objective is achieved (or the percentage of added phases becomes zero).
7) Repeat step 6 until a relationship between the association rate and the added rate is obtained.
8) Choose a point where the added rate is lower than a given percentage, say 20% (first priority) and the association rate is a set percentage, say 10%, (second priority).
9) Test the modified recipe by running the DFX application.

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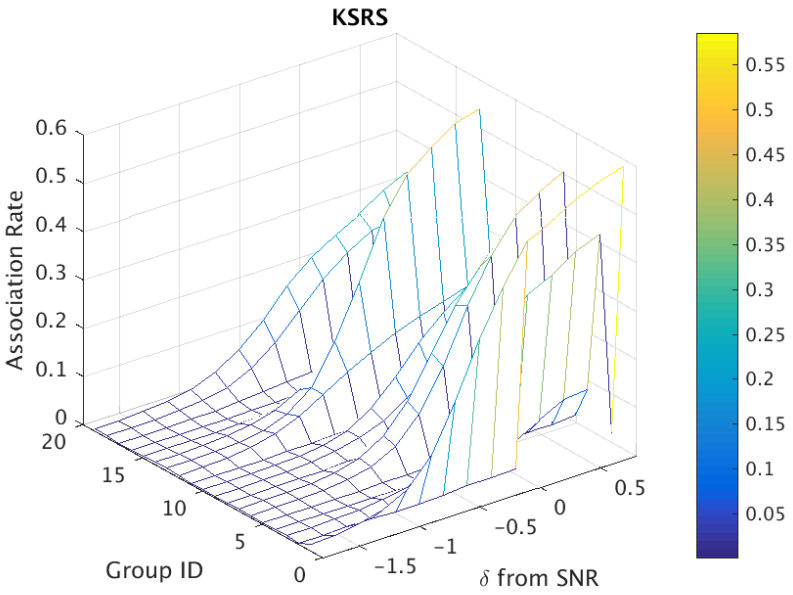

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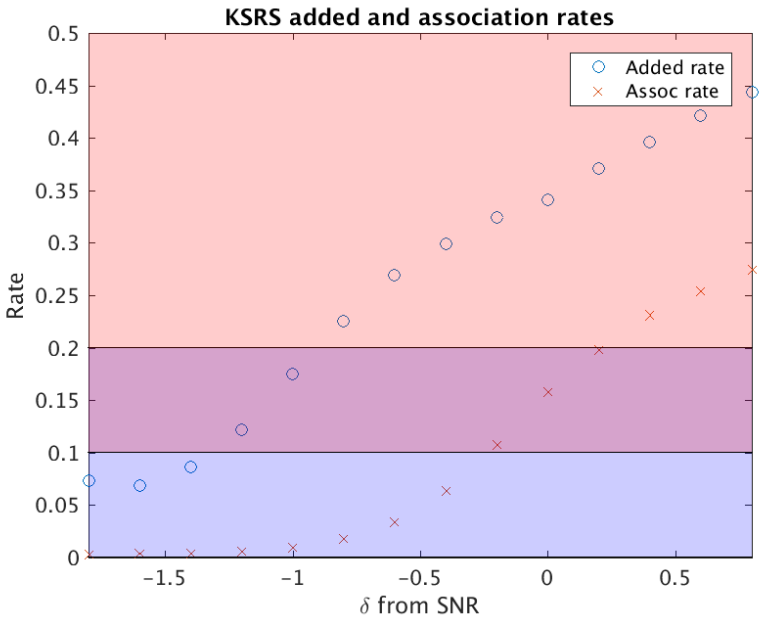

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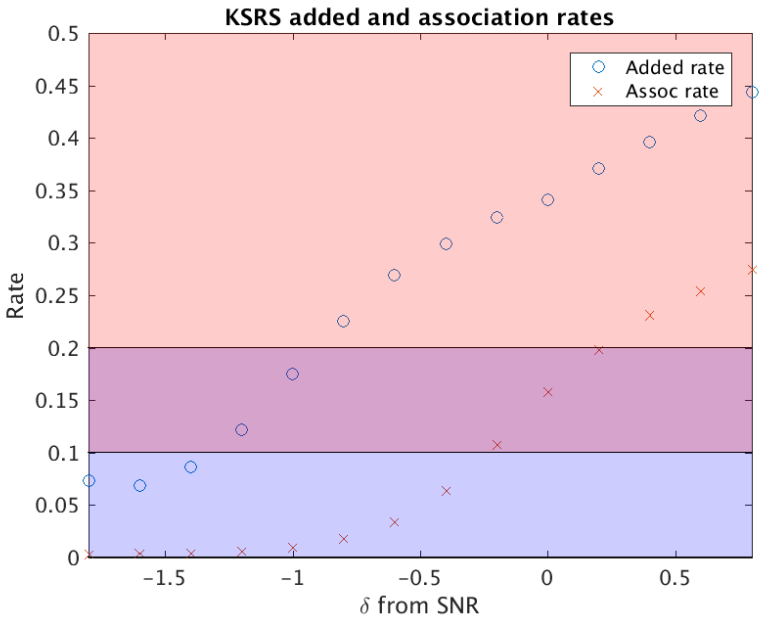
Increment is not specified; **0.2** is taken



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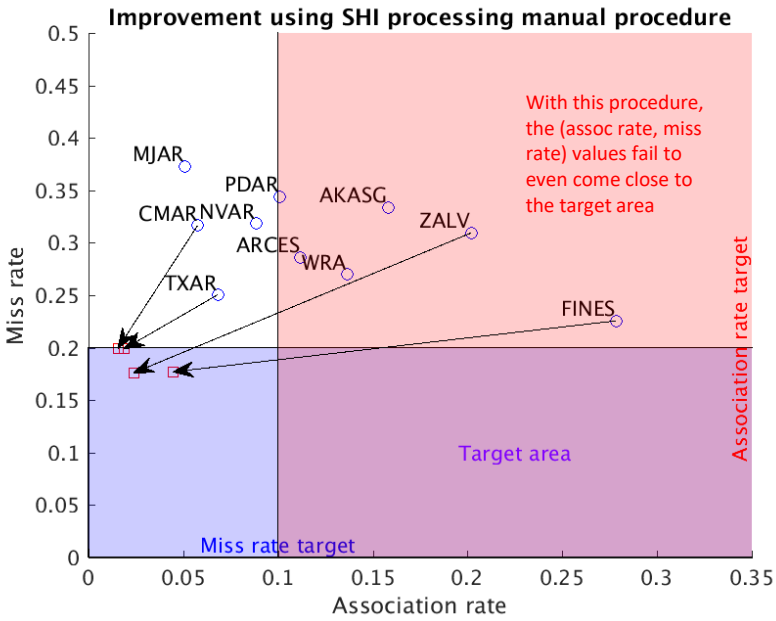

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Optimization using a hybrid grid/genetic algorithm search

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The algorithm

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{
 initialize population;
 evaluate population;
 while Termination_Criteria_Not_Satisfied
 {
  select parents for reproduction;
  reproduction (aka crossover);
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Individuals in population: beam threshold combinations

Initial population includes

- Current beam thresholds
- Exhaustive grid search for 7 most prolific beam groups

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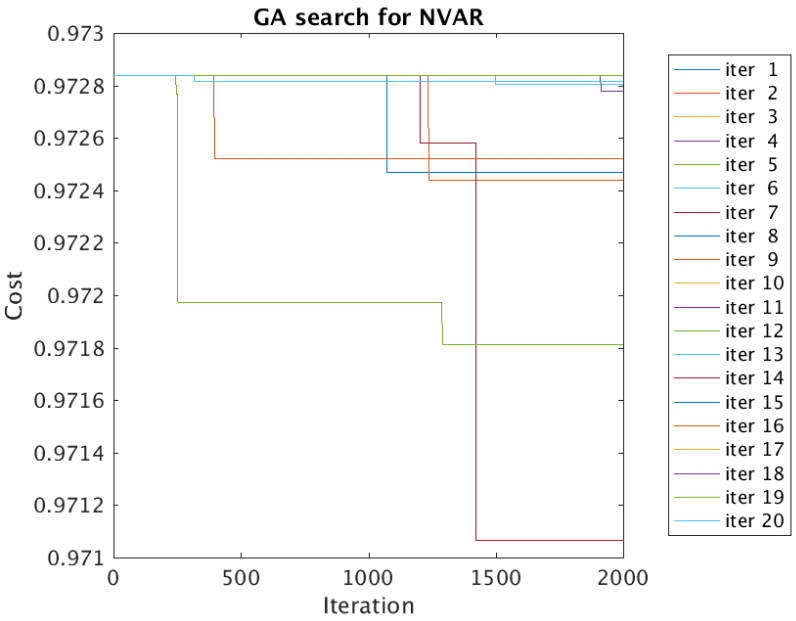

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Cost function

$$C(\text{individual}) = \begin{cases} \infty, & \text{if added rate} > 0.2 \\ 1 - \text{assoc rate}, & \text{if added rate} \leq 0.2 \end{cases}$$

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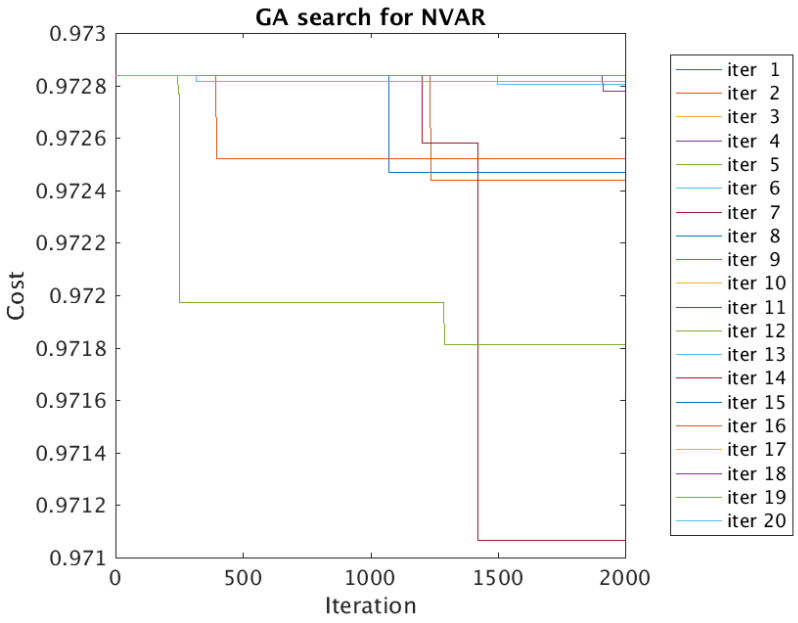

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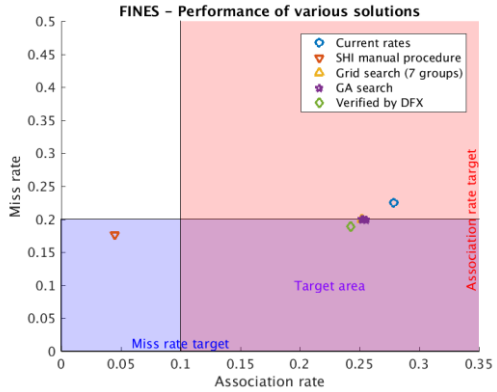

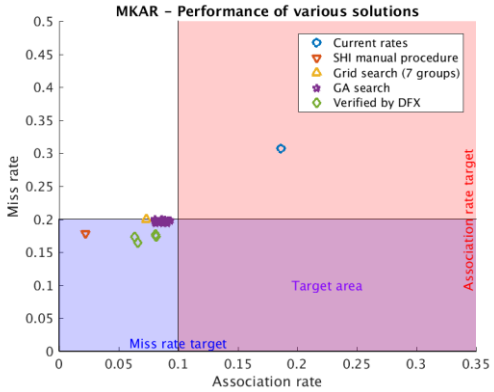

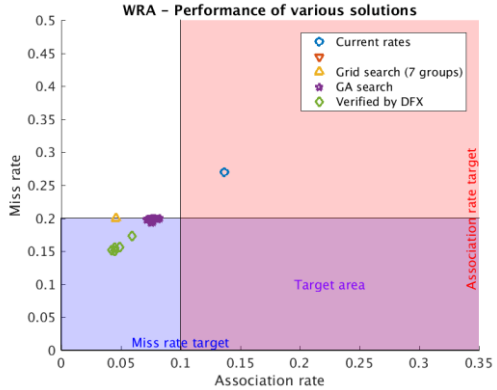

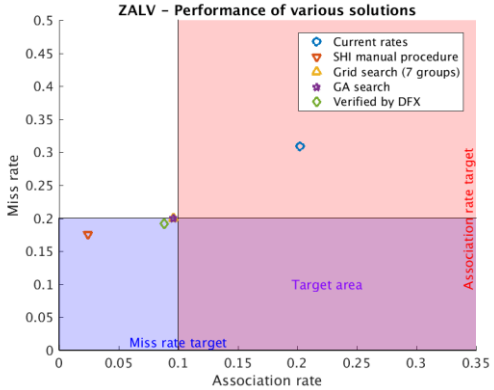

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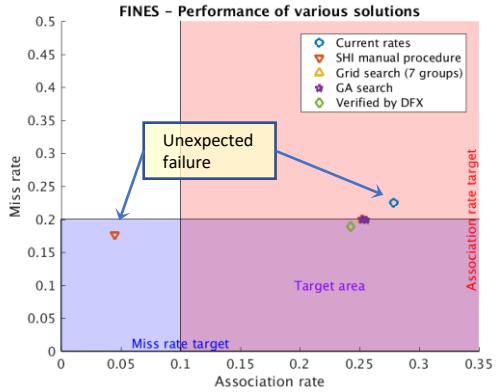

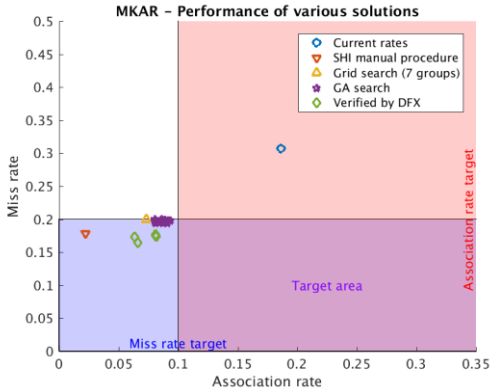

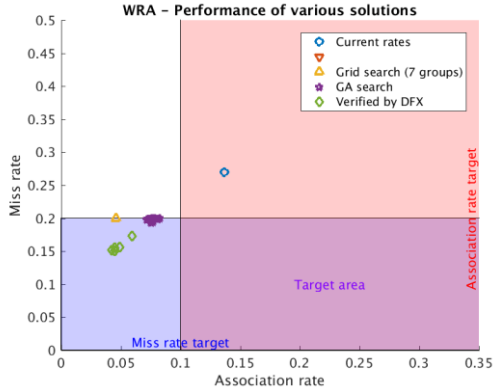

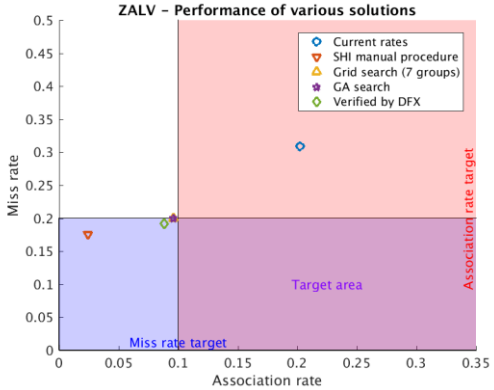

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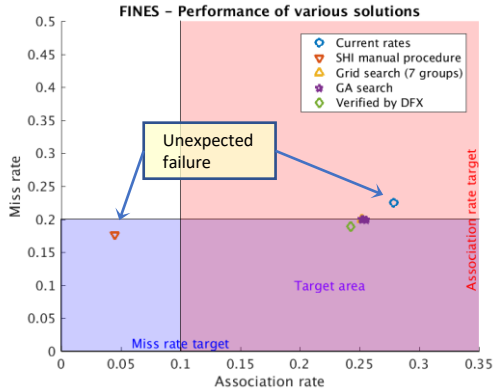

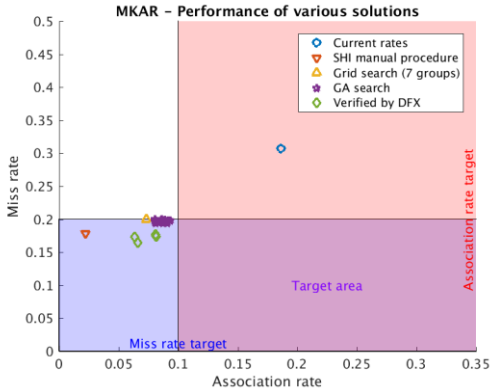

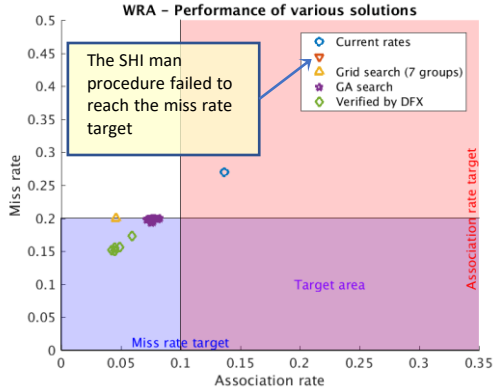

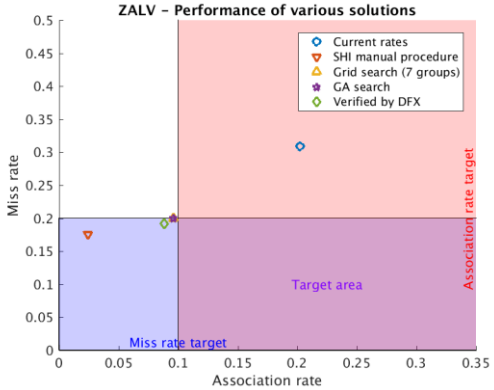

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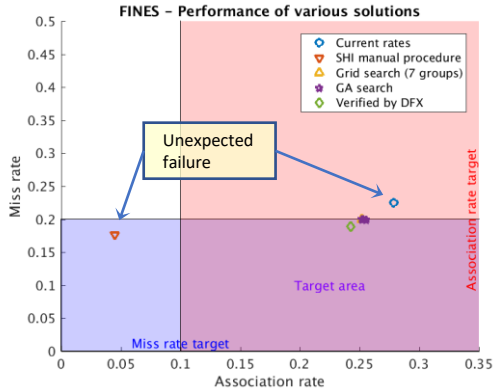

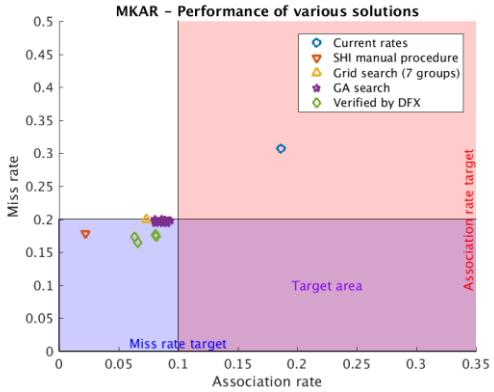

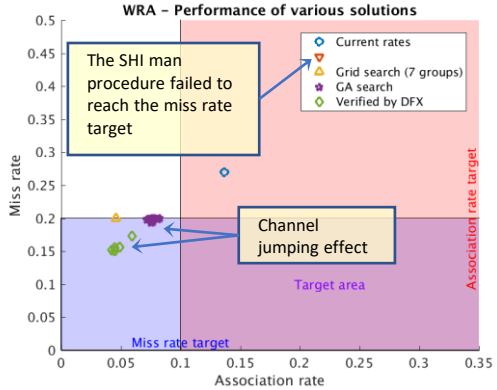

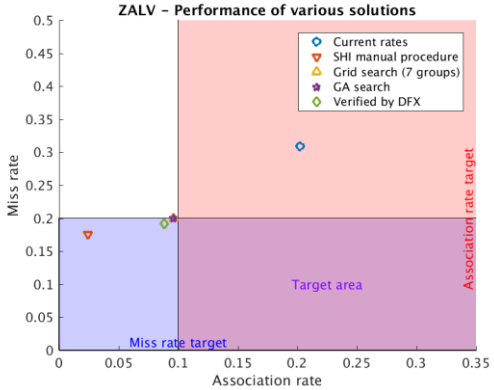

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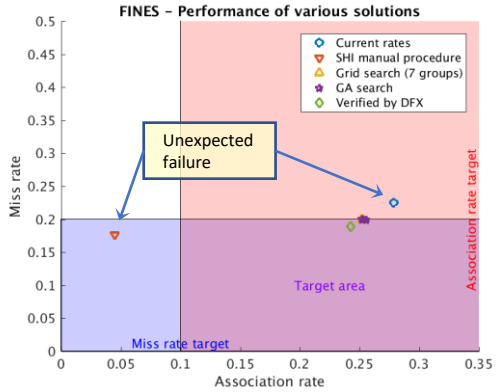

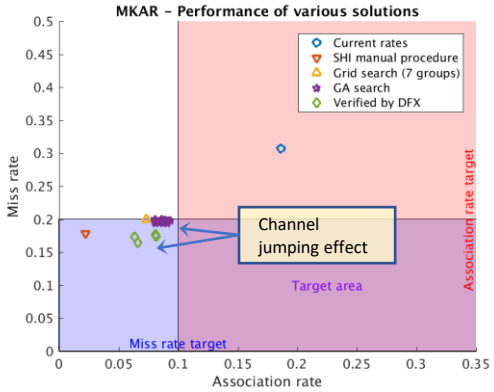

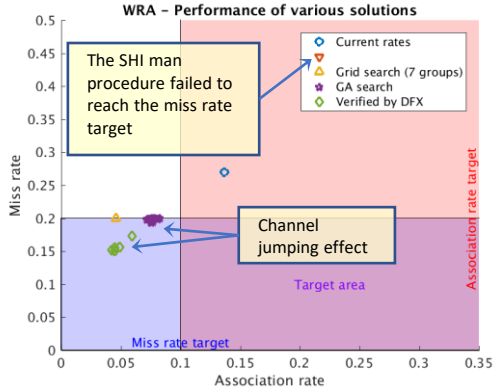

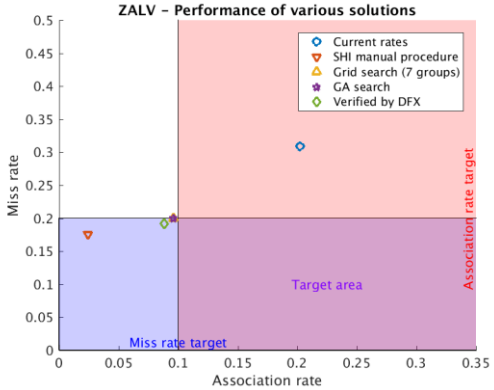

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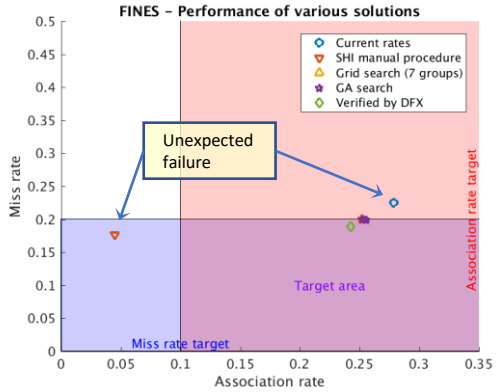

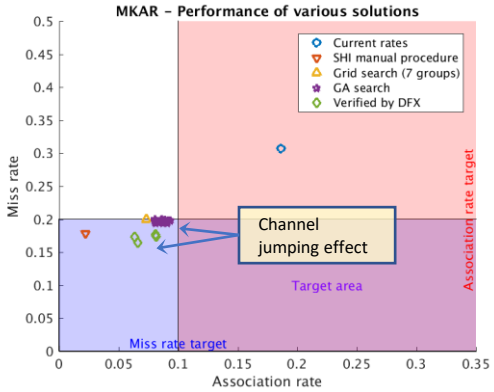

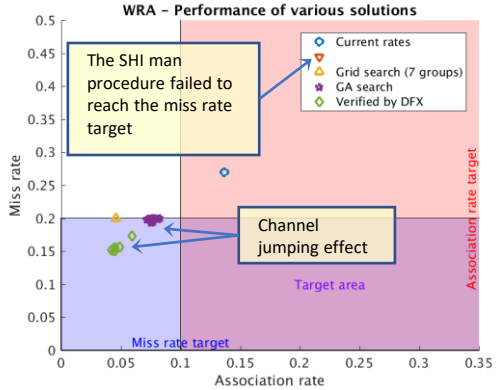

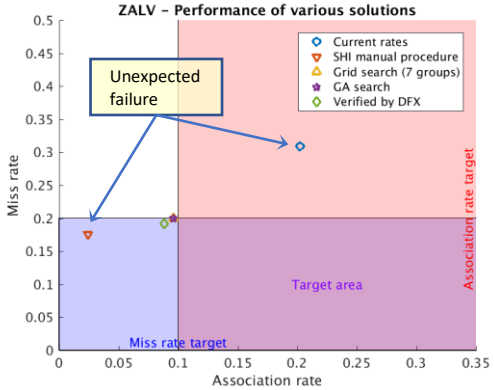

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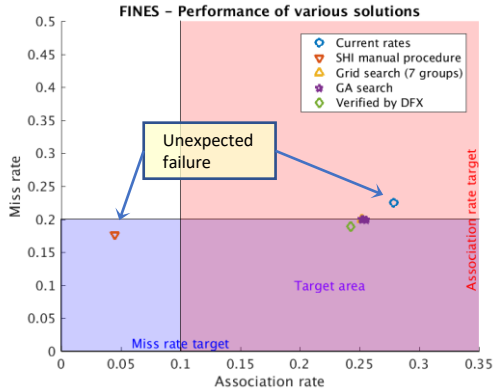

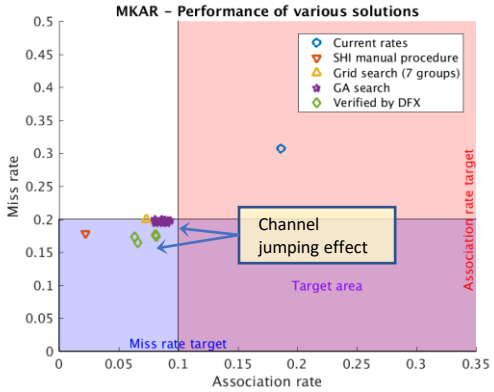

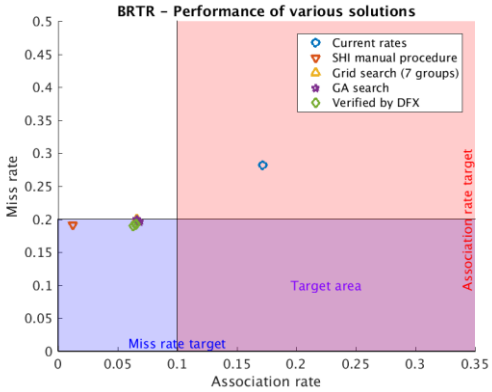

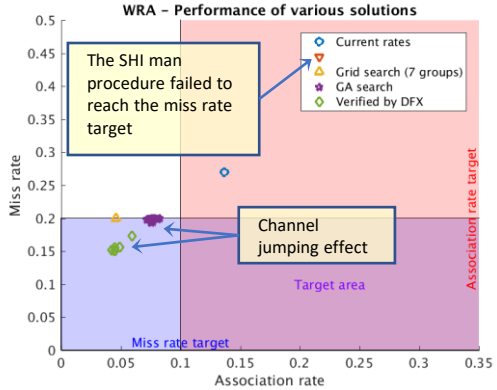

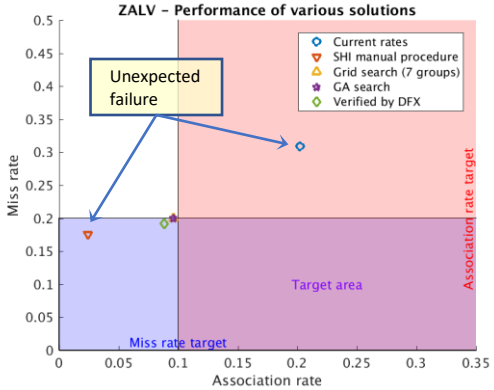

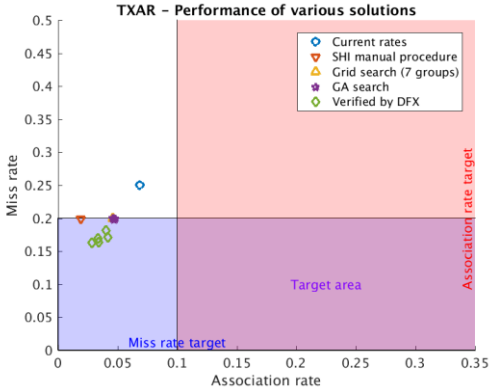

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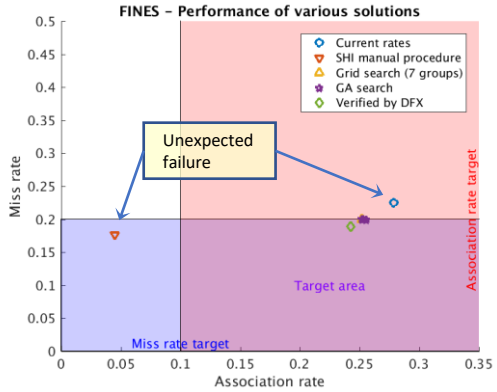
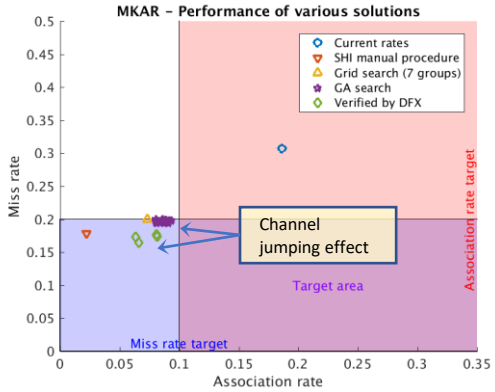
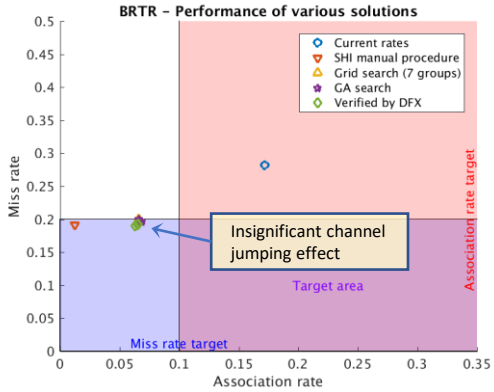
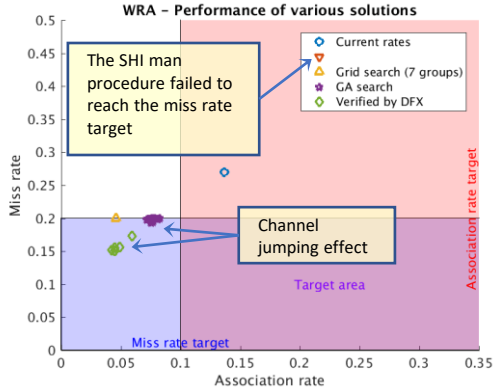
Christos Saragiotis and Ivan Kitov, CTBTO, IDC/SA/SM

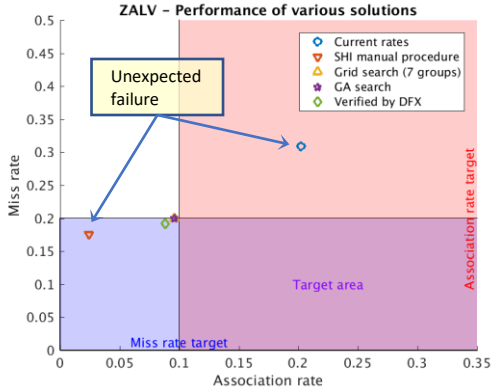
RESULTS

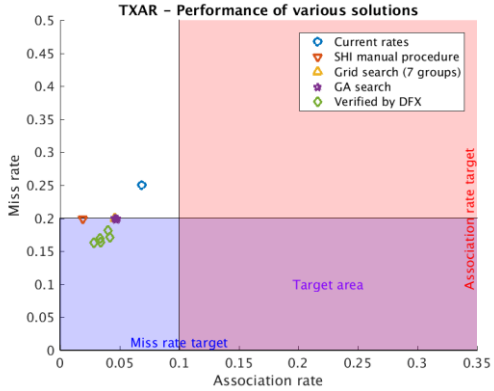












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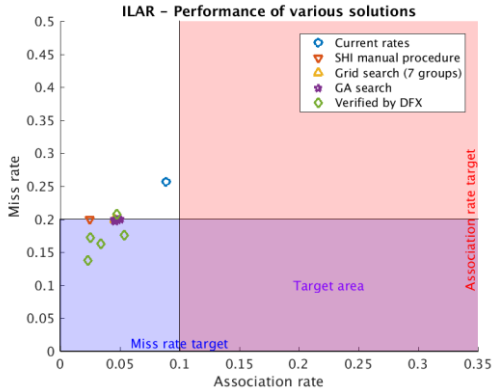

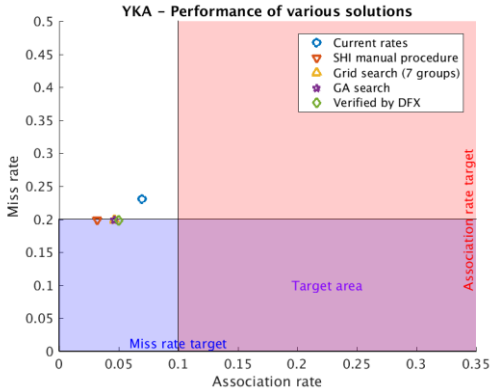

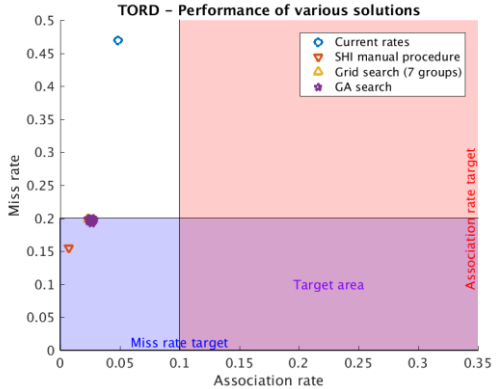

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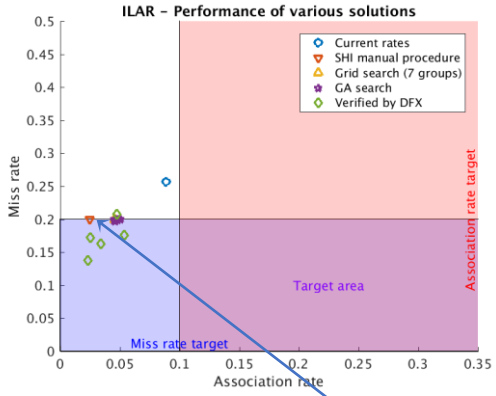

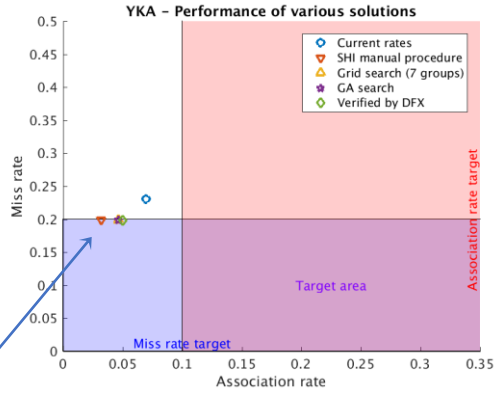

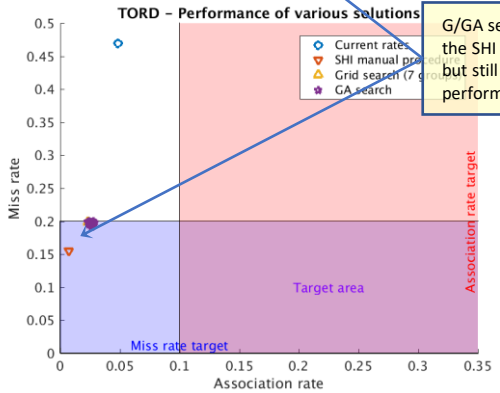

G/GA search outperforms the SHI man procedure but still not satisfactory performance

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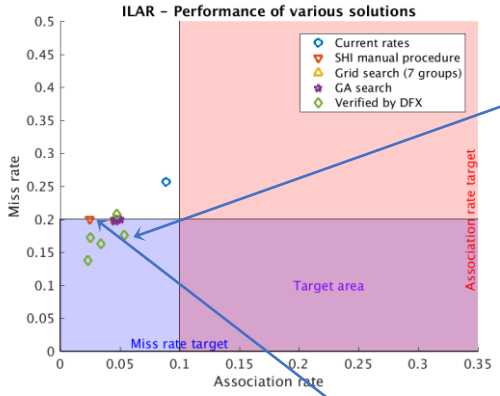
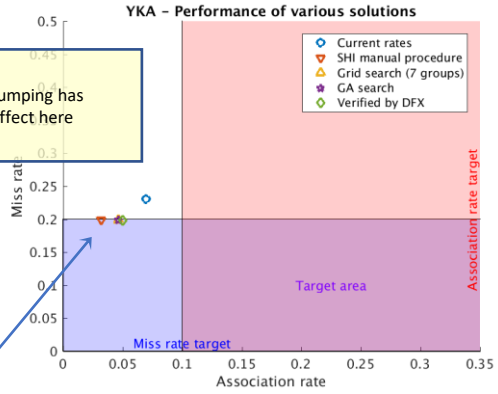
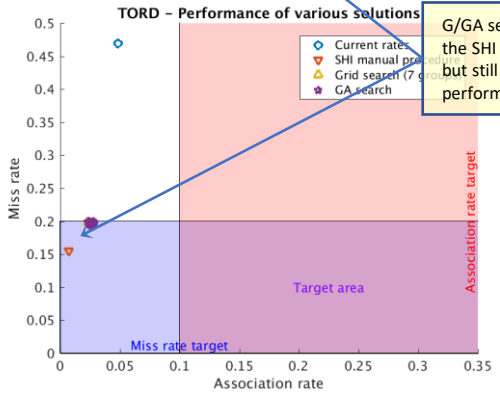




Channel jumping has positive effect here



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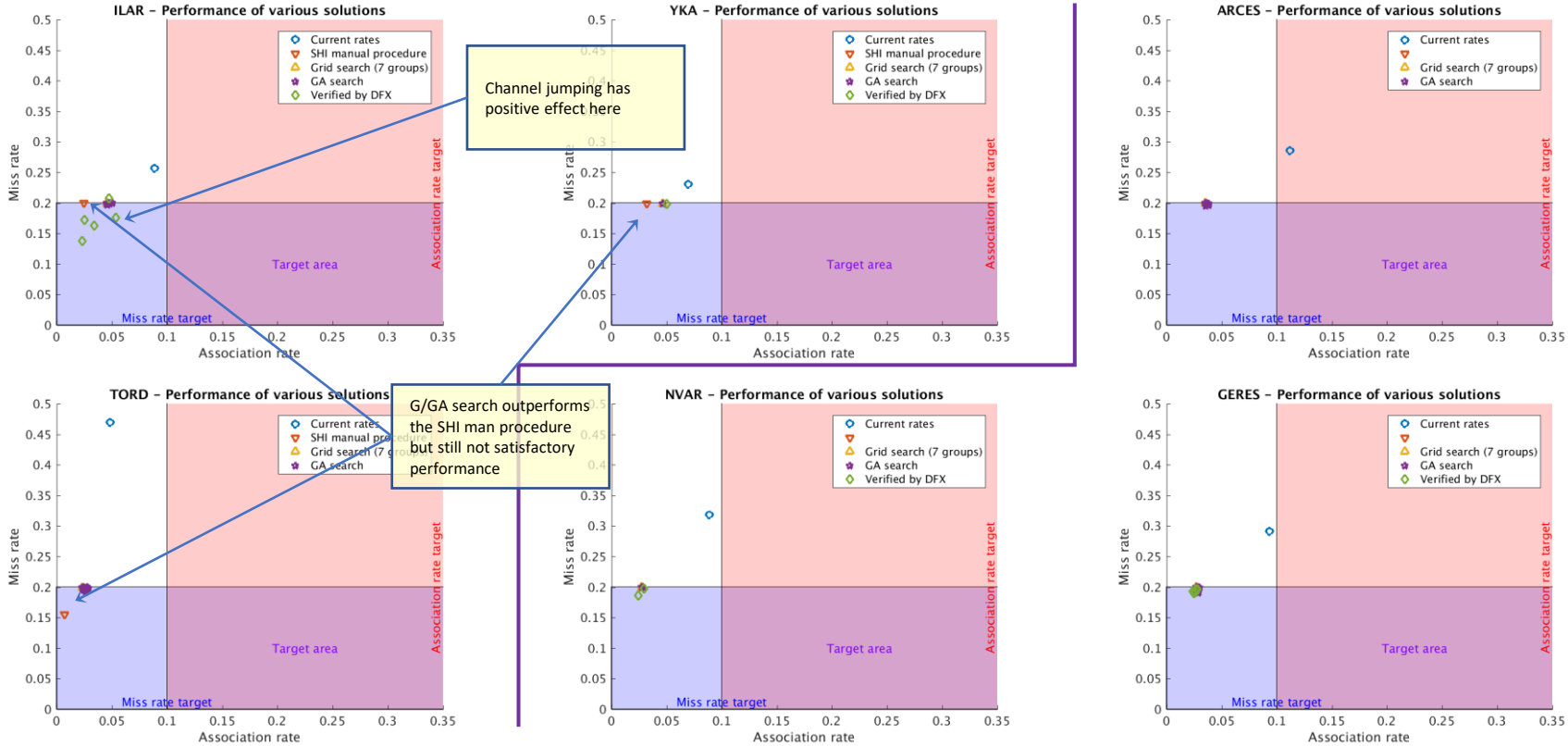
CTBTO PREPARATORY COMMISSION

RESULTS



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

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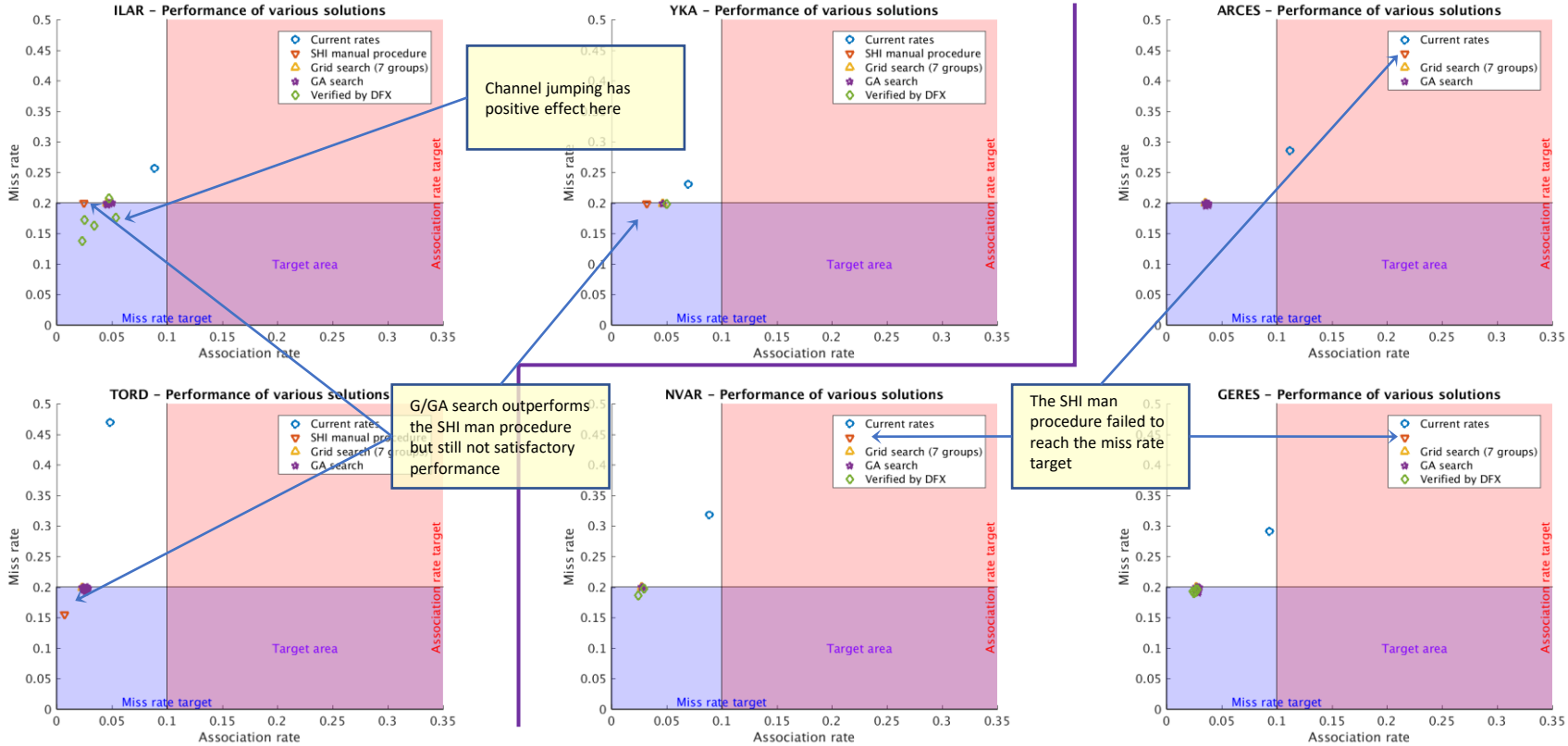

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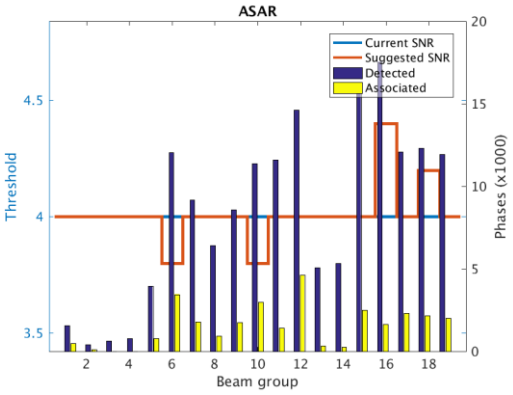

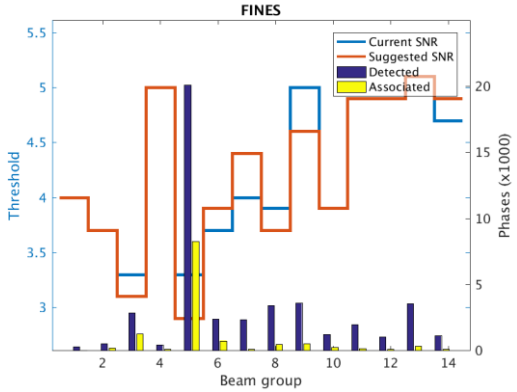

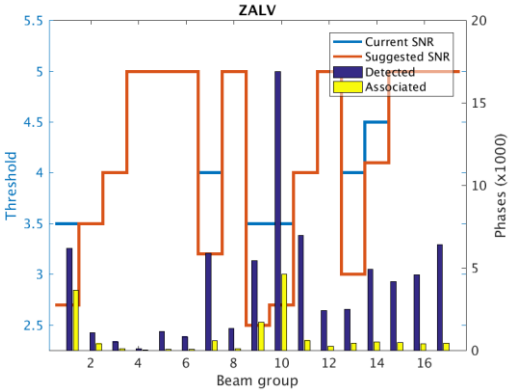

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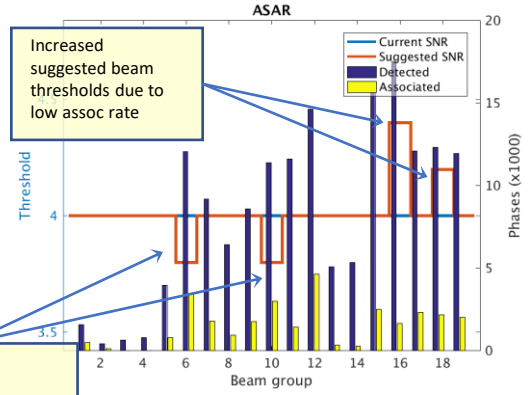

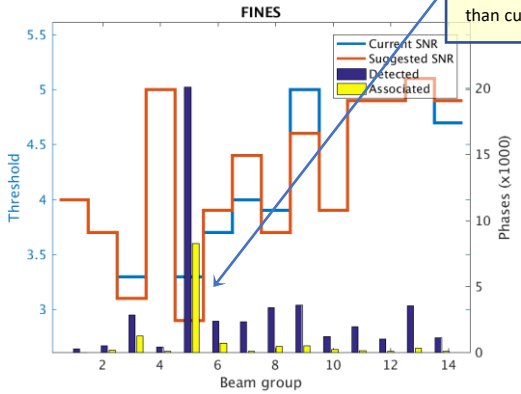

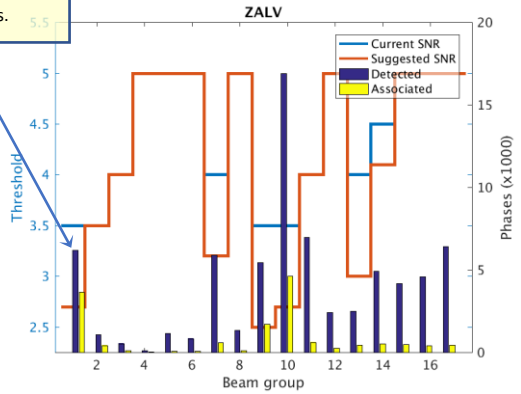

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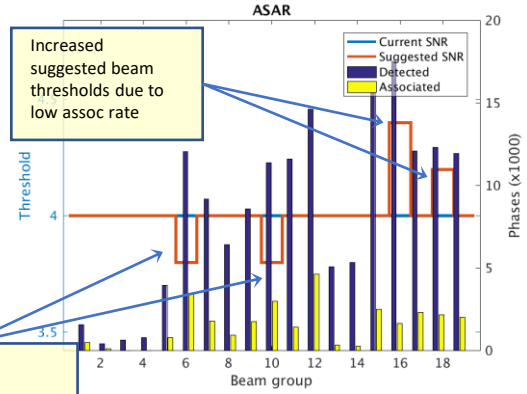
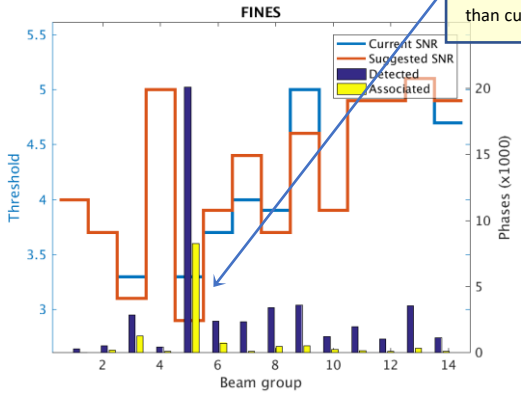
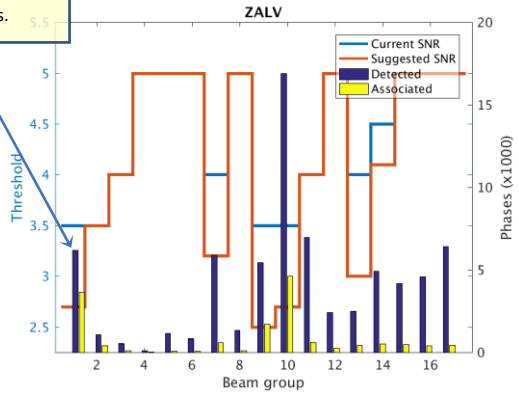
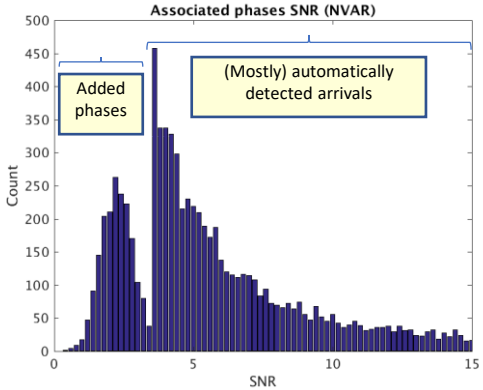






For some stations it seems not possible to increase the association rate when forcing the miss rate below 20%.

One reason for this is that there are phases added by the analysts that have extremely low thresholds. These phases are impossible to be matched and cause an artificial bias to the added rate score.



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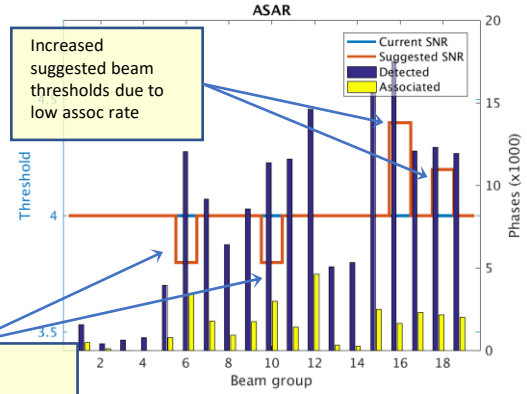

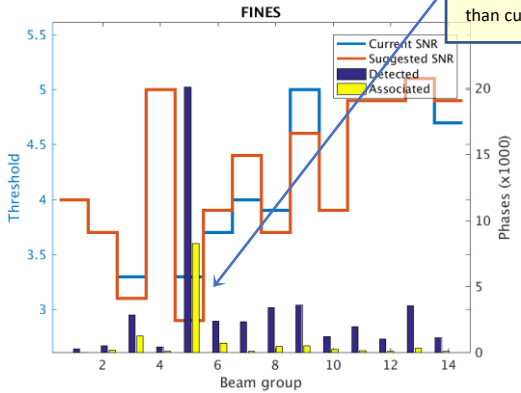

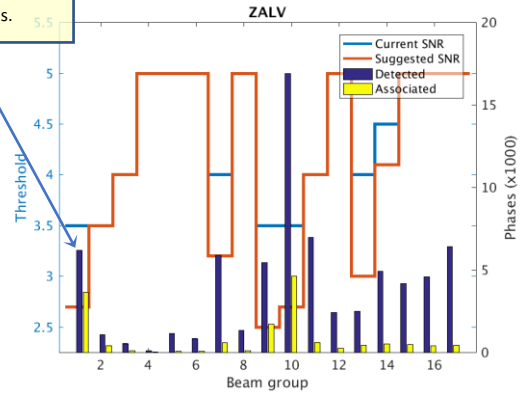

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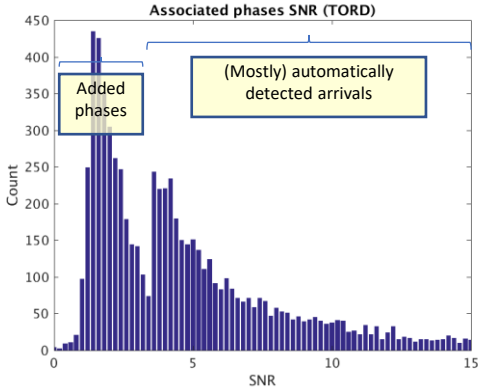

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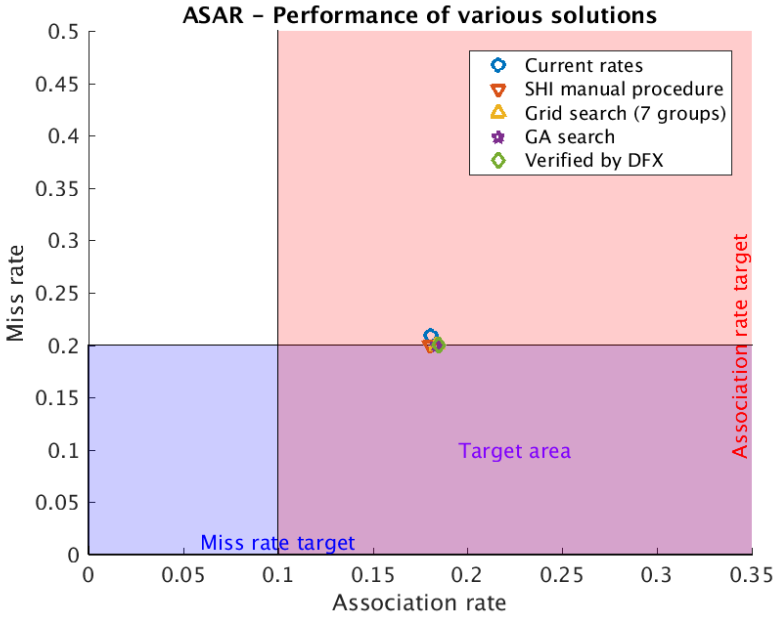
CONCLUSIONS



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- Priority is given in reducing the miss rate (adding phases is much more time consuming than disassociating them)
- The number of combinations of beam thresholds to be checked for each station is astronomical.
  - **Exhaustive grid search** is impossible
  - **Suggested procedure in manual** is very fast but suboptimal in most cases; in some cases, it **completely fails** to achieve the target for the miss rate
  - A **hybrid grid/genetic algorithm search** seems to yield quite better results.
- Some stations seem to not be able to achieve sufficiently high association rate; this may be due to:
  - phases with very low SNR added by the analysts (e.g., mining blasts) or
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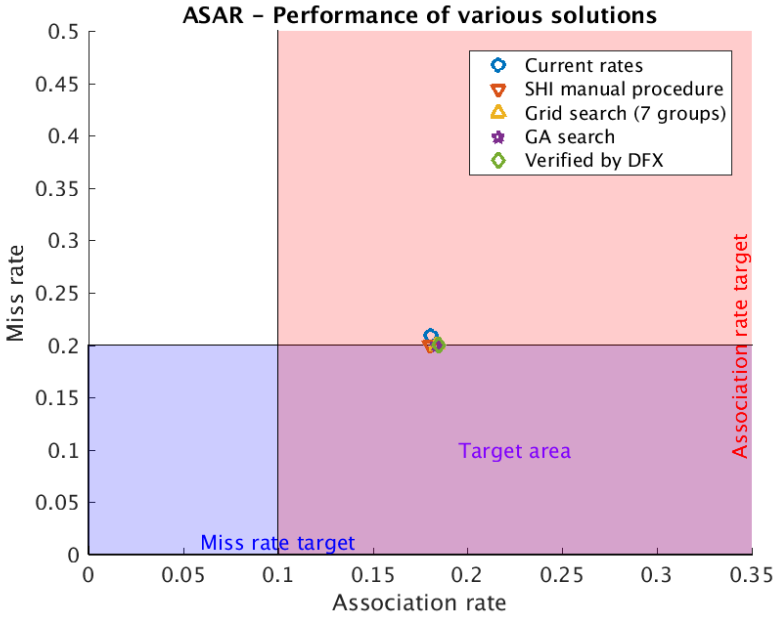
- The **channel jumping effect** causes both the association and miss rates to decrease; higher miss rate could therefore be considered as the target rate.



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Future work

- **Apply** the hybrid grid/genetic algorithm search to **remaining** primary array stations
- **Assess** the **channel jumping effect** of the new beam threshold sets
- Test the new beam thresholds online to **include automatic association** (using GA or NetVisa)
- Examine rates **excluding** **very** **low SNR added phases**.