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The Application of a Dynamic Correlation Processor for International Monitoring System (IMS) Detection Screening

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P3.5-198

POSTER

Lawrence Livermore National Laboratory

NNSA National Nuclear Security Administration

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC. LLNL-PRES-822532

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ABSTRACT

The vast majority of International Monitoring System (IMS) seismic detections are associated with small events that are detected by only one station. Large numbers of small-event detections at each IMS station increase the probability of the International Data Centre (IDC) automatic system building false events. We test whether detections of small, repeating local events (e.g., mines) can be identified and screened prior to the IDC association process. We use a dynamic correlation processor (DCP) (Harris and Dodge, 2011) to form groups of similar waveforms, and we then manually associate these groups to known mines and other sources. We first test screening at the Norwegian Arctic ARCES IMS array by applying the IDC beam recipe to the incoming data steam, then using the DCP software to group events. Preliminary results on this array show that for two beams, 80% and 74% of automated detections are found by DCP and may be screened before IDC preprocessing. These promising results suggest that the DCP screening method may be used to identify and screen detections that are not of interest to monitoring before they are passed to the IDC automatic system. Detection screening may significantly reduce analyst effort to produce the Reviewed Event Bulletin.

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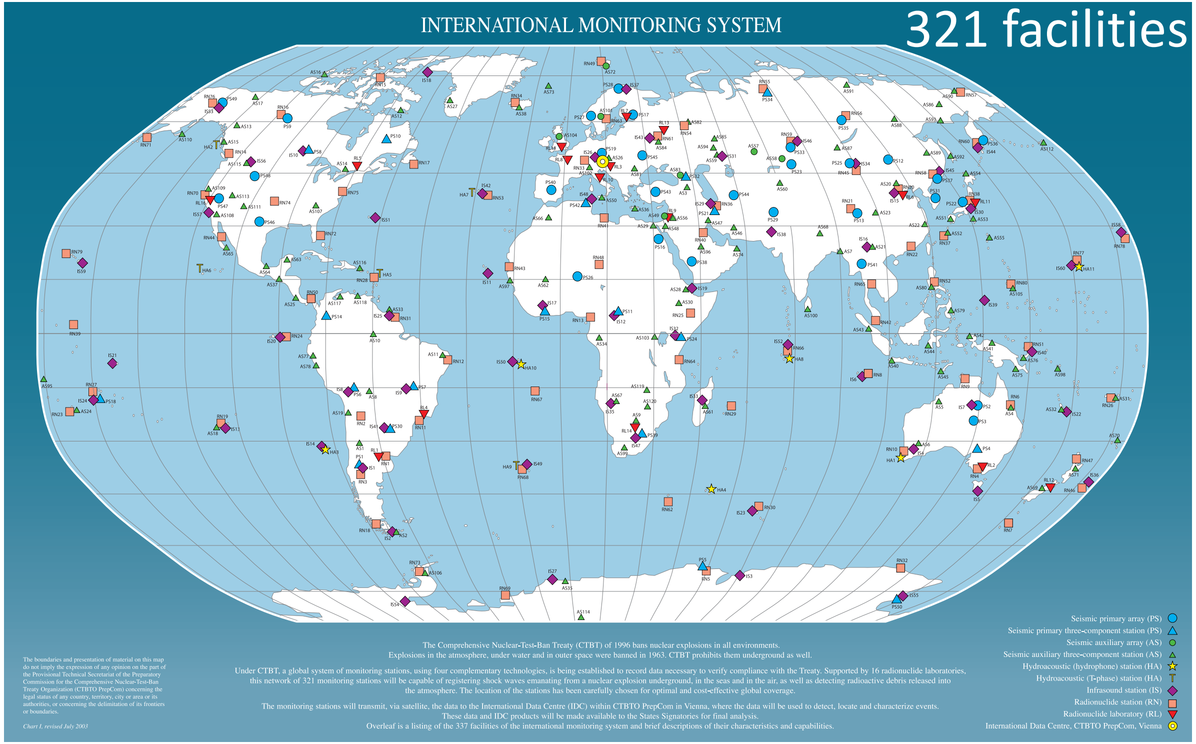
INTRODUCTION

International Monitoring System (IMS)

- The IMS collects measurements and data for nuclear explosion monitoring.
- Global networks of seismic, infrasonic, hydroacoustic and radionuclide sensors.
- Seismic Network:
  - Three-component stations
  - Seismic arrays
- Data gets processed at the International Data Centre (IDC)



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INTRODUCTION

International Data Centre (IDC)

1. Data fed to automatic detector that operates on individual data streams (stations)

2. Global associator (e.g., GA and/or NetVISA) determines which detections originated from a common source (event)
   - Arrival time is the dominant characteristic used to associate detections,
   - Other detection characteristics like amplitude, back-azimuth, and slowness may also be used by the associator

3. The automatically generated bulletin (SEL1) is reviewed by analysts who generate the Reviewed Event Bulletin (REB)
   - Significant numbers of erroneous associations are linked to small events detected at single stations

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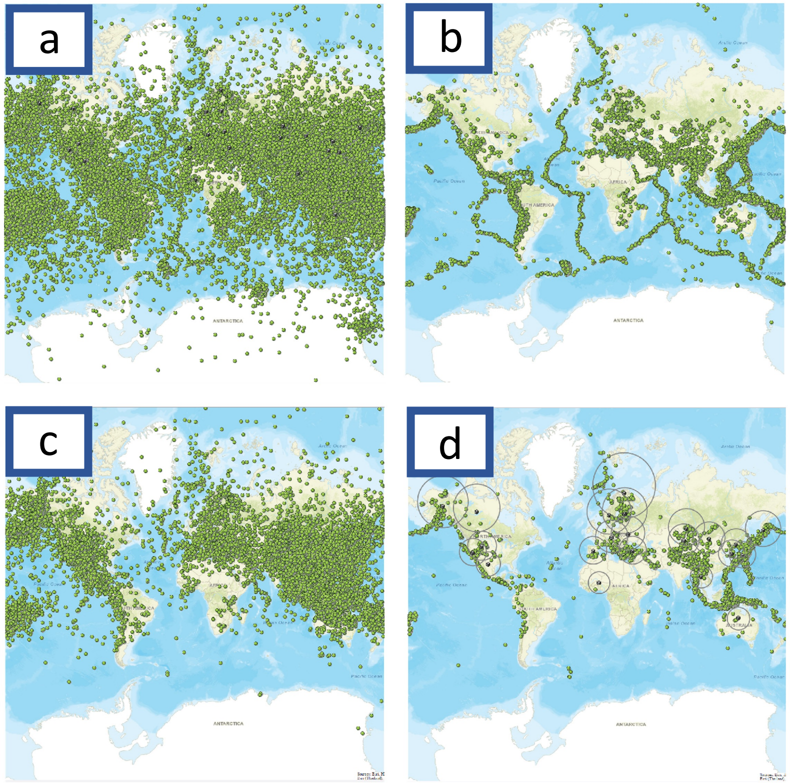
INTRODUCTION

The Challenge: Producing the REB is a labor-intensive process

- Deconstructing false events and building events that were missed by the automatic system is time consuming and can result in late publication of the REB.
- Formation of false events through association of signals from numerous small events that are detected only at one station is known to be a significant problem.
- Many of these nuisance signals are from repeating sources that may be identified based on template matching and screened prior to being fed to the association process.

a) 57193 events in the SEL1 bulletin in 2019
b) 30297 REB origins for 2019
c) 30848 SEL1 origins with at least one arrival with a DFX slowness >= 0.1 s/km (limit detections local/regional sources)
d) 4524 REB origins with at least one arrival having a DFX slowness >= 0.1 s/km (limit detection local/regional sources)

(DFX are Pn, P, Lg detections from IDC automated detection system)



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METHODS

How Can We Address This?

Detection screening process to identify repeating signals from small, local-distance events recorded at only one International Monitoring system (IMS) station.

Dynamic Correlation Processor (DCP)

(Harris and Dodge, 2011)

- Screening of these signals
- **Success** = Fewer false events and more real events formed by IDC automatic system
  - This will translate into a significant reduction in analyst effort to produce the REB

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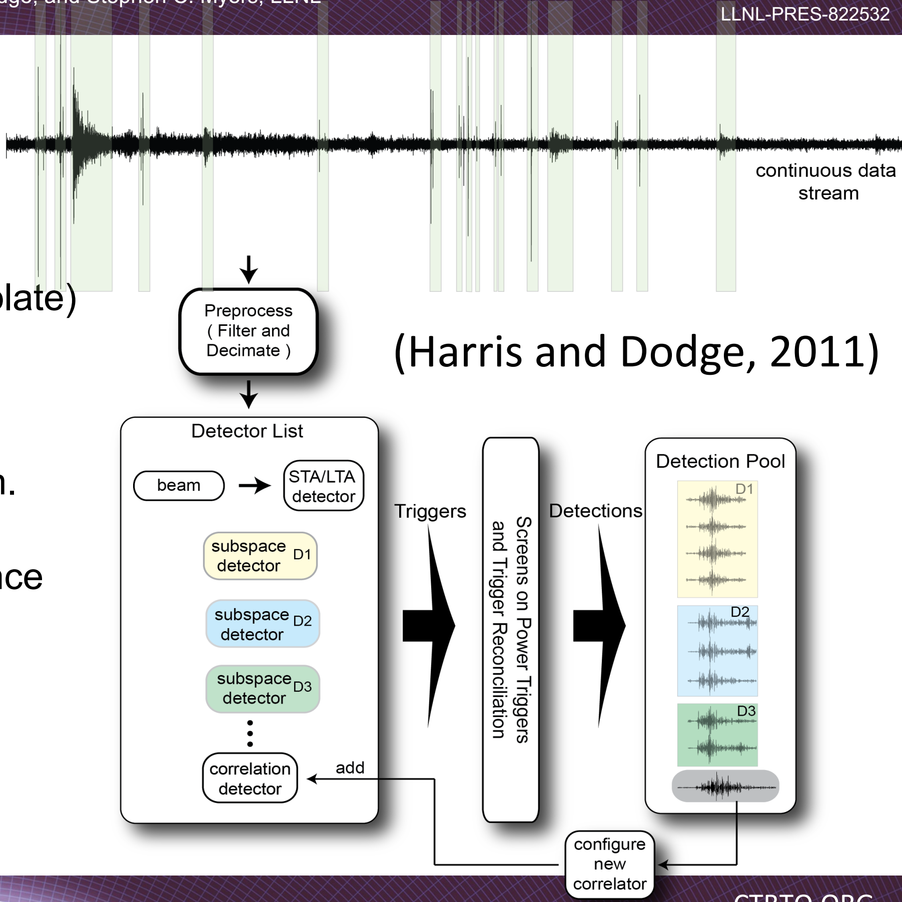
METHODS

Dynamic Correlation Processor

1. Power detector
2. Window waveform to create correlation detector (template)
3. Recursively use detectors to build a waveform family
4. Reduce the waveform family to a subspace detector
5. Apply the subspace detectors to incoming data stream.

- Correlation triggers are always selected in preference to power detector triggers.
- For triggers belonging to a single detector type (correlation or power), the trigger arising from the largest detection statistic value is selected.



(Harris and Dodge, 2011)

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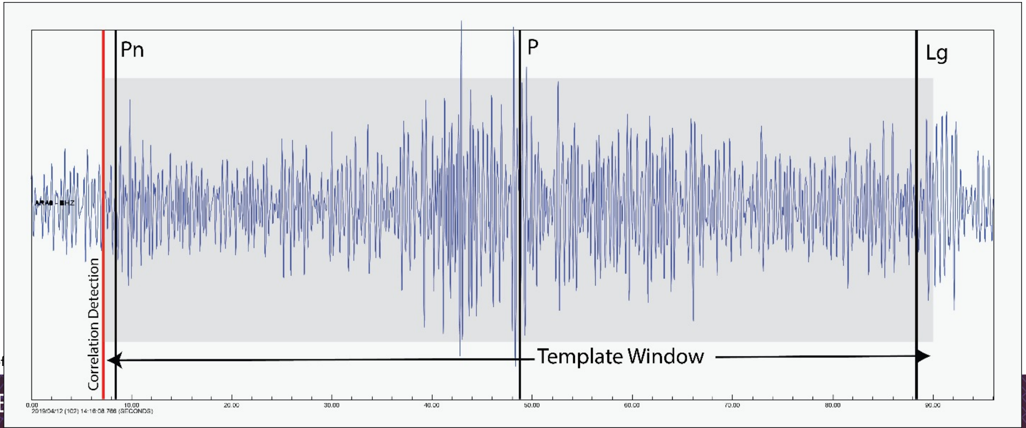
METHODS

In this Study

- Apply DCP processing to 23 IMS arrays in the first 316 days of 2019
- Manual detector editing:
  - All detector sets with fewer than 5 waveforms were eliminated.
  - Remaining detectors time aligned and used to make new subspace detectors
- **DCP** and **IDC** detections were associated by station and time



Example association between DCP (correlation) detection and 'IDC system' DFX detections. DFX detections that fall within the ***DCP template*** *are associated to DCP detection.*

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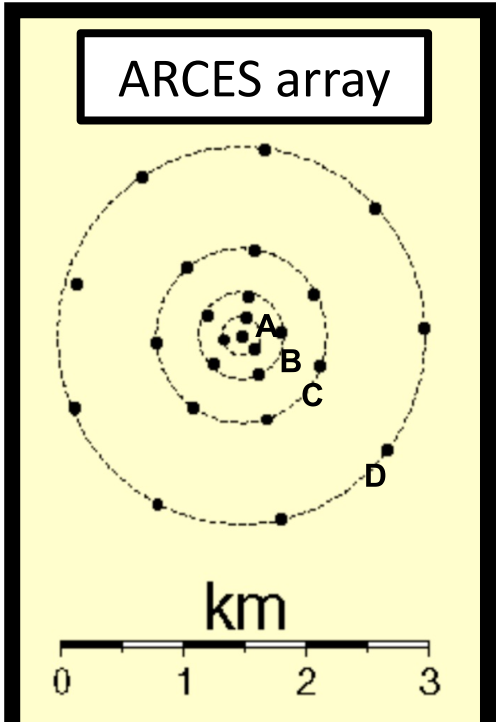
METHODS

In this Study

- **DCP** usually applies a wideband pre-filter to achieve a large time-bandwidth product for robustness
- **Instead** we use preprocessing filters used by IDC. As an example, ARCES has 4 narrow band beam spread: (constructed from the output of many sensors)

1. 25 beams (0.75 to 2.25 Hz). Center element + C, D rings. (Velocities 3, 8, 13, and infinite km/s)
2. 25 beams (1 to 3 Hz). Center element + C, D rings. (Velocities 4.5, 8.7, 17.3, and infinite km/s)
3. 37 beams (2 to 4 Hz). Center element + B, C, D rings. (Velocities 3.5, 6, 10.5, 21, and infinite km/s)
4. 10 beams (3 to 6 Hz). Center element + B, C, D rings. (Velocities 10.5, and infinite km/s)



NORSAR network report (2015)

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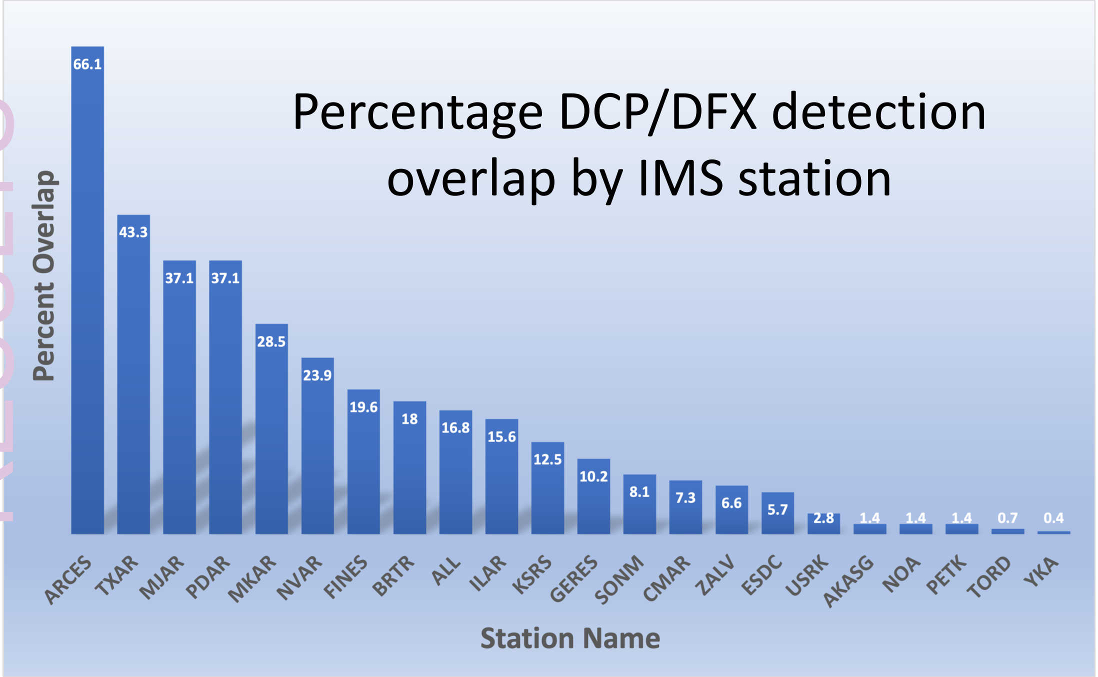
RESULTS



In 2019:

- 1,766,396 total **DFX** detections
- 1,190,544 **DFX** detections with slowness >= 0.1 s/km
- **DCP** processors produced 384,355 detections from repeating sources with slowness >= 0.1 s/km in same period.

200,290 **DFX** detections are associated with “slow” **DCP** detections, ~17% of **DFX** detections could be screened from consideration by the global associator or have limitations placed on their hypothesized locations.

The percentage of **DCP-DFX** overlap varies greatly among the arrays ranging from 0.3% at WRA to 66.1% at ARCES

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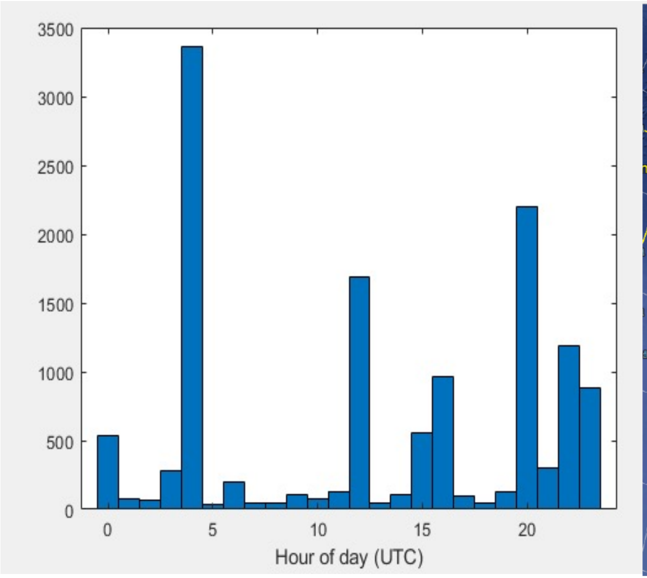
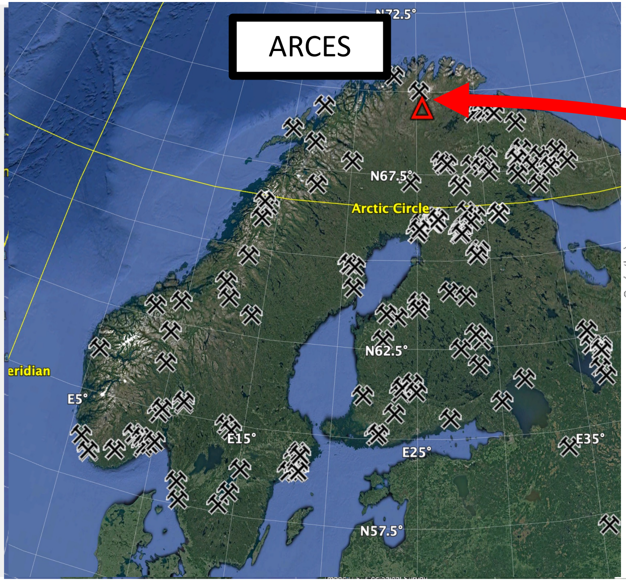
RESULTS

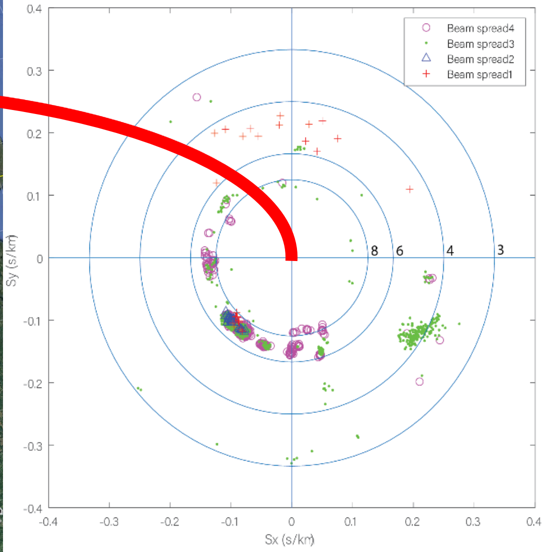
ARCES Screening Candidates Largely from Industrial Sources



Time of day for top 100 detectors (local time is UTC+3)



ARCES array and locations of mines in the surrounding region (https://mrdata.usgs.gov/)



Slowness plot of **DFX** detections that are candidates for screening

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RESULTS

IDC's Weighted-Count Test

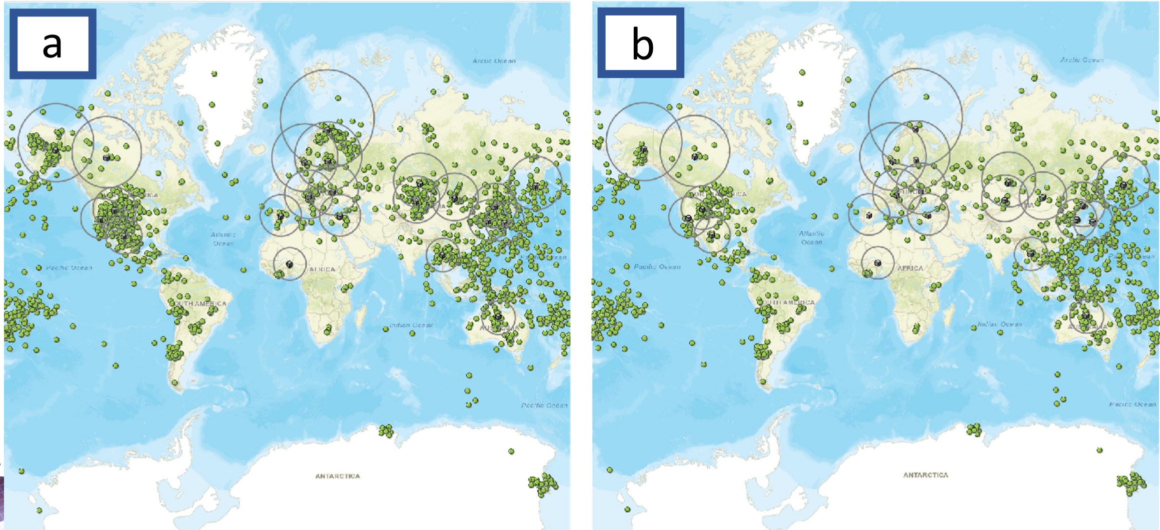
We estimate the effectiveness of screening prior to production of SEL1 by using the IDC's weighted-count test. Each arrival is assigned a weight and the sum of the weights must be greater than a threshold. This figure shows potentially screened events with 10-degree circles centered on the arrays.

Phase weights for event definition in SEL1, SEL2, AND SEL3 (chapter 5, IDC user guides)

Phase Type	Station Type	Arrival Time	Azimuth	Slowness
primary seismic	seismic array	1.0	0.4	0.4
secondary seismic	seismic array	0.7	0.4	0.4
primary seismic	seismic 3-C	1.0	0.2	0.2
secondary seismic	seismic 3-C	0.7	0.0	0.0
H	hydroacoustic	1.2	0.6	0.0
I	infrasonic	1.0	0.4	0.4

a) 3627 (6.3%) SEL1 origins screened based on weighted-count test score <= 3.55 after removing all arrivals associated with one or more **DCP** detections.

b) 1314 (2.3%) SEL1 origins discarded only if they failed to meet the weight score and if one or more arrivals associated to **DCP** detections was at a station located outside 10-degree radius.



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CONCLUSIONS

- A significant fraction of the detected signals are from repeating sources such as mines and other industrial sources. Such signals can be detected and grouped efficiently using the **DCP** software. This organization of repeating signals may provide a basis for screening **DFX** detections and improve the quality and efficiency of building the SEL1 bulletin.

- We processed data from 316 days in 2019 for 23 IMS primary arrays arranged in 55 different beam configurations and obtained 394,644 detections from 19,889 detectors of repeating sources. We associated **DFX** detections with these **DCP** detections based on time and found that 4.8% of the study set **DFX** detections and 22% of slow set **DFX** detections were associated. Although 189,349 of these associated **DFX** detections did not make it into SEL1, removing these from consideration could alter the hypotheses created by the GA associator.

- For detections that made it into SEL1 as arrivals, we estimated the effect of screening by applying the IDC weighted-count test for the SEL1 origins with and without the associated **DFX** detections. We found that up to 6.3% of the SEL1 hypotheses could be discarded if all **DFX** detections from repeaters were screened.