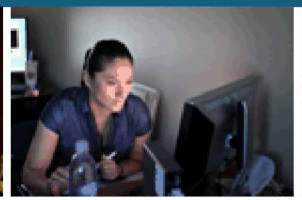
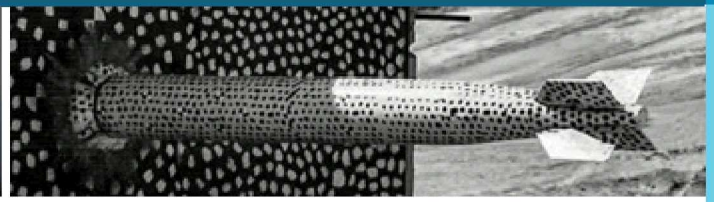
SAND2020-10505PE

Reducing IDC Analyst Workload: Applying Waveform Correlation to Mining Blasts





Amy Sundermier, Rigobert Tibi,

Ronald A. Brogan, Christopher J. Young

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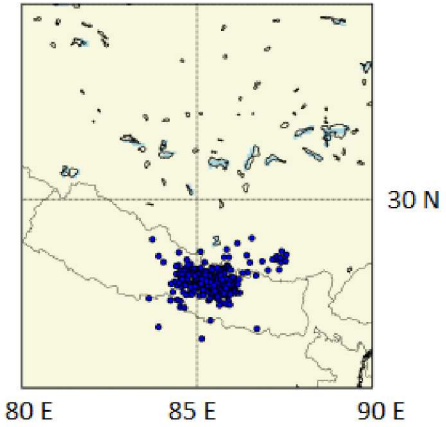
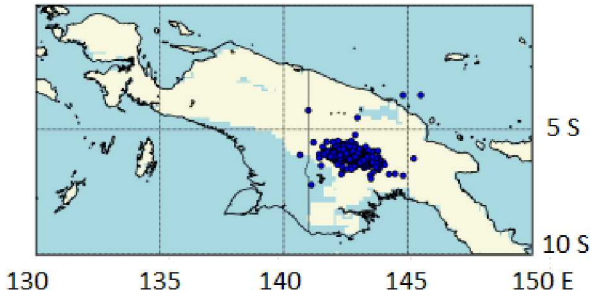
Provisional Technical Secretariat (PTS) Initiated Study of Waveform Correlation Techniques to Detect 2 Types of Recurring Events

Aftershocks

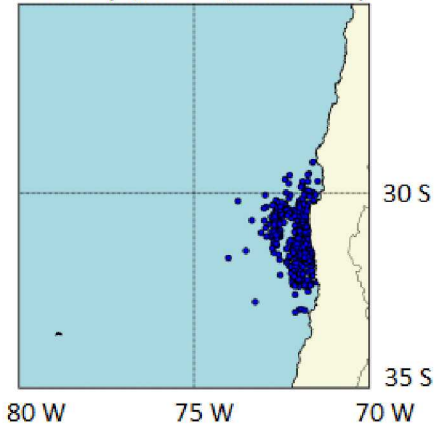
Nepal (4/2015, 7.8 Mw)



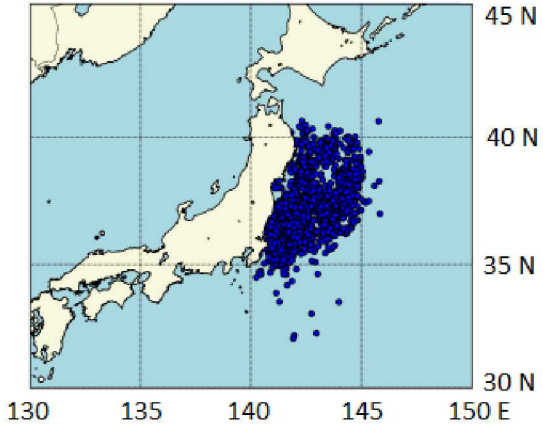
Papua New Guinea (2/2018, 7.5 Mw)



Chile (9/2015, 8.3 Mw)

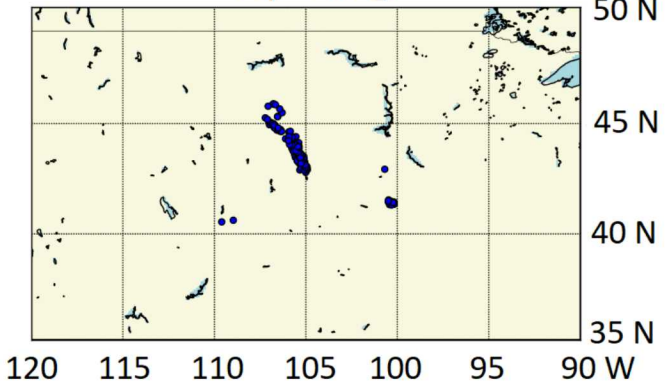


Tohoku (3/2011, 9.0-9.1 Mw)

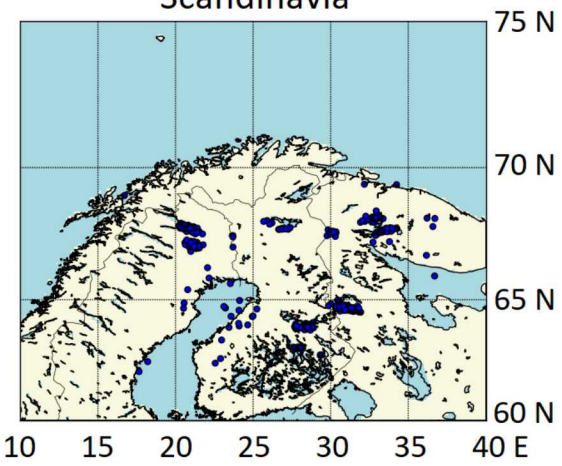


Mining Blasts

Wyoming



Scandinavia



IDC Automated Pipeline Background

Automated pipeline detects signals, associates signals to events and locates events

Automated pipeline produces Standard Event Lists (SEL)

- SEL1 includes primary seismic and hydroacoustic station arrivals
- SEL2 includes auxiliary seismic, infrasound and any late arrivals from primary seismic and hydroacoustic
- SEL3 includes late arrivals of all phenomenologies

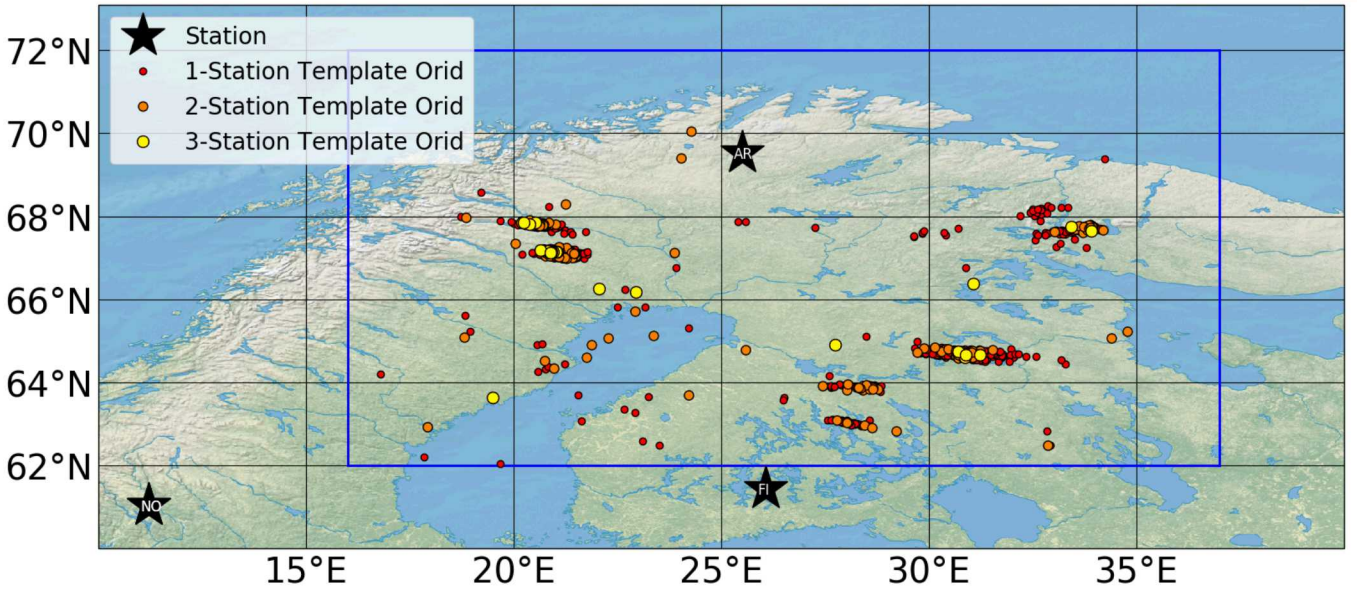
Analysts review SEL events, change associations, etc. to produce REB

Can waveform correlation improve the automated pipeline to reduce analyst workload?

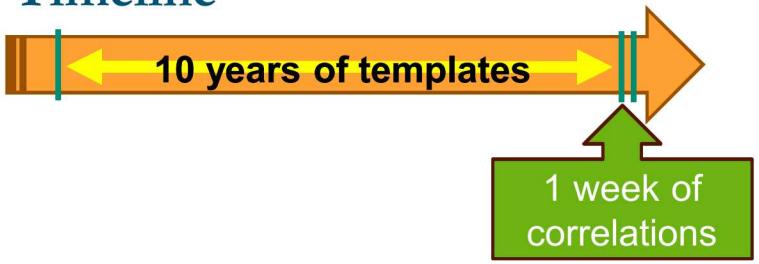
Mining Blasts Study

Experimental Setup

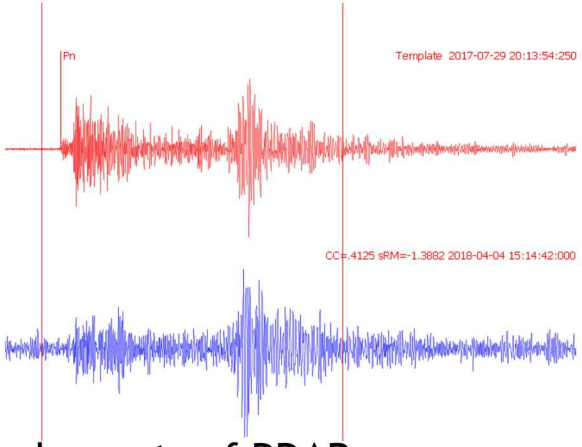
- Up to 10 years of templates for 3 stations prior to week of study
- Correlate over two 1-week periods



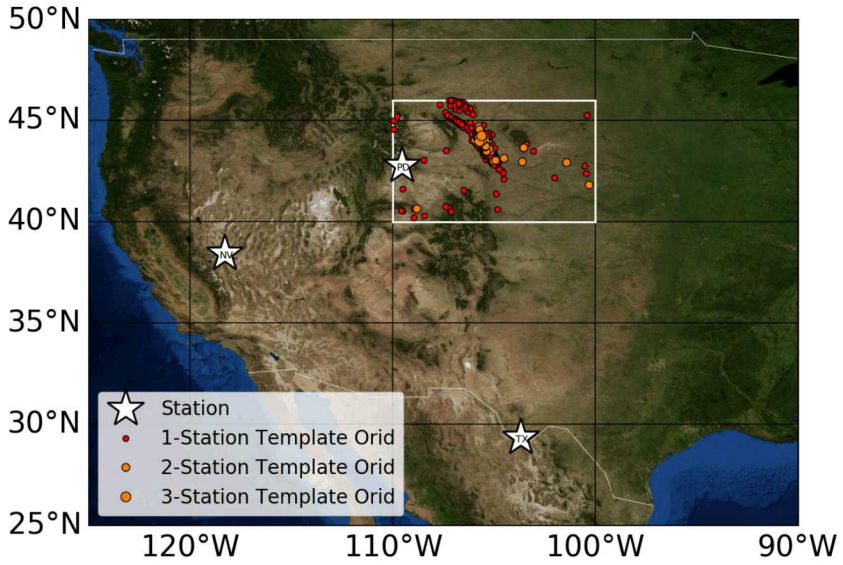
Timeline



Example Template
PDAR, 80 s, Pn phase

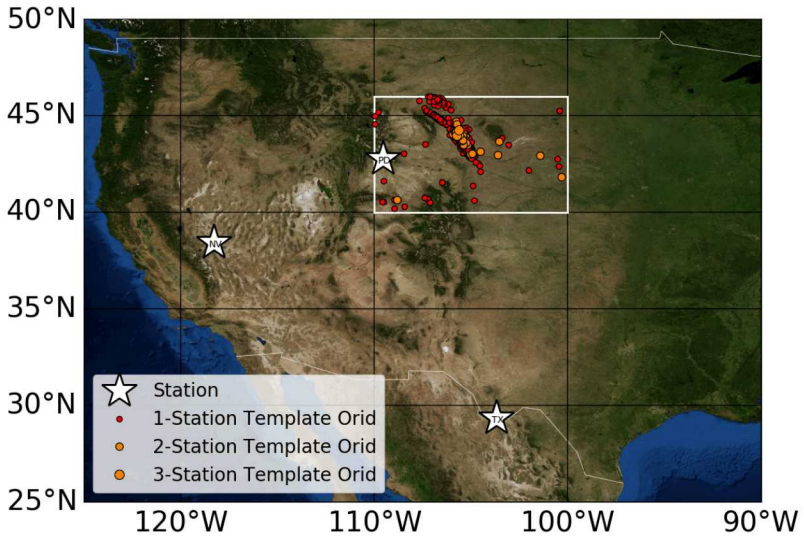


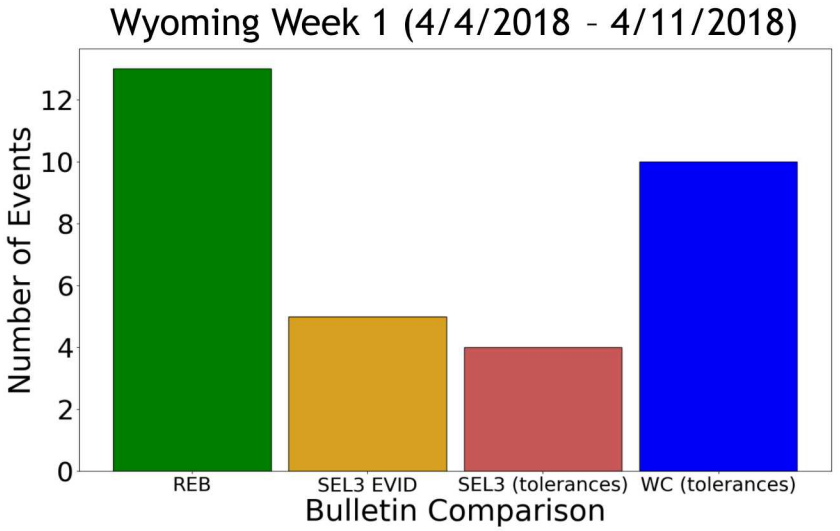
Detection
CC score = 0.4125
composite score for 13 elements of PDAR

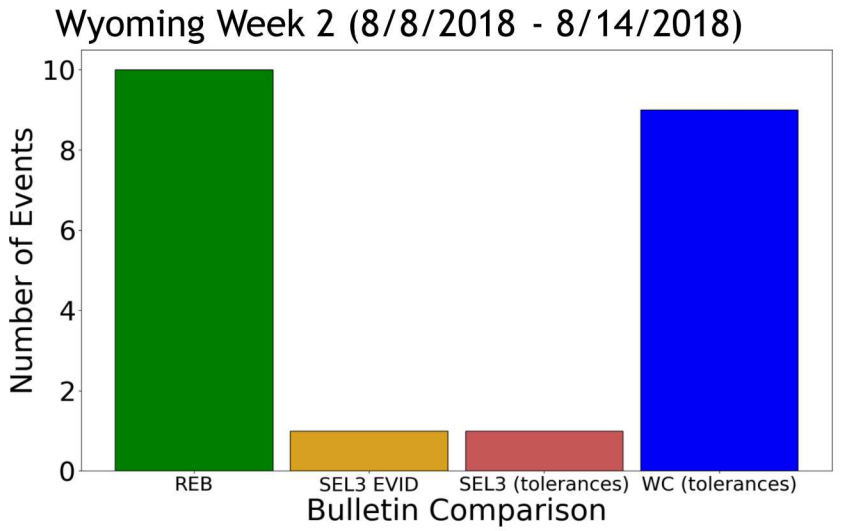


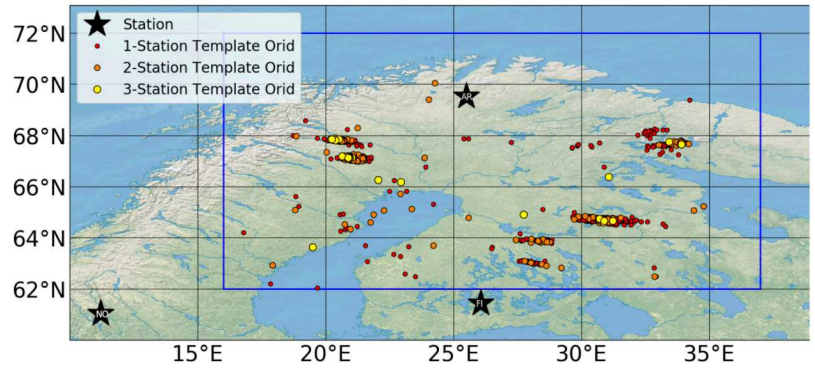
Results Overview

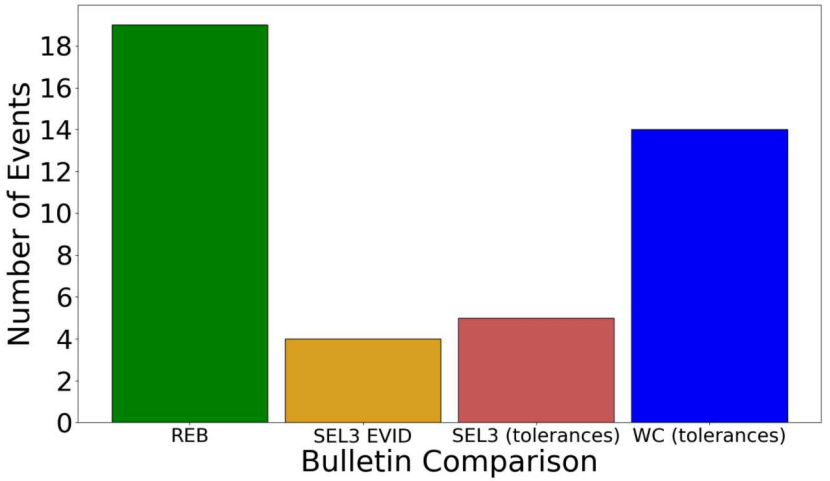
Event comparison tolerances (1.0°, ±15s)

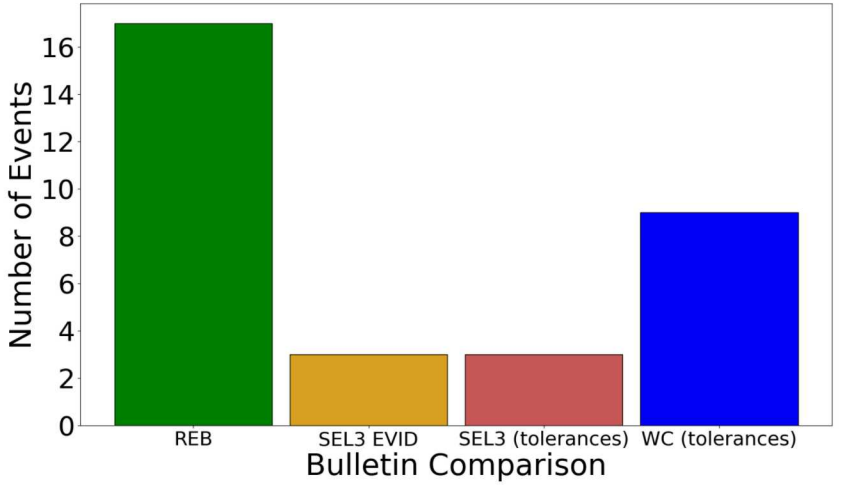








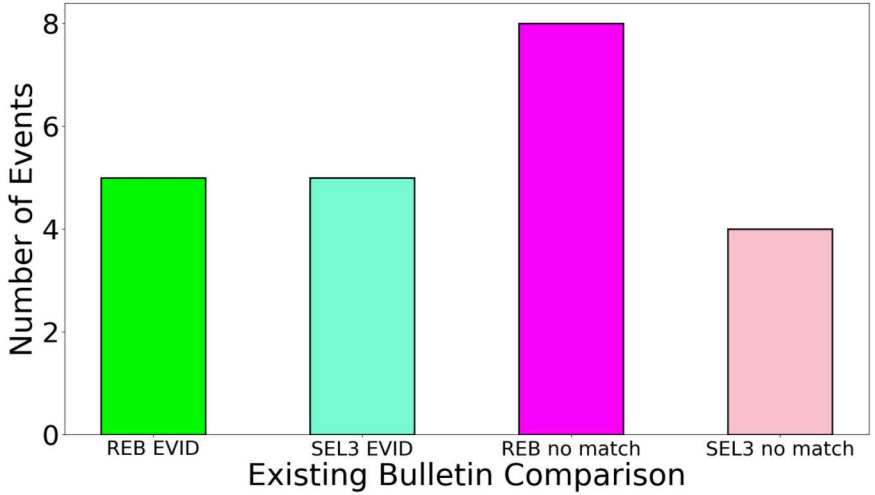


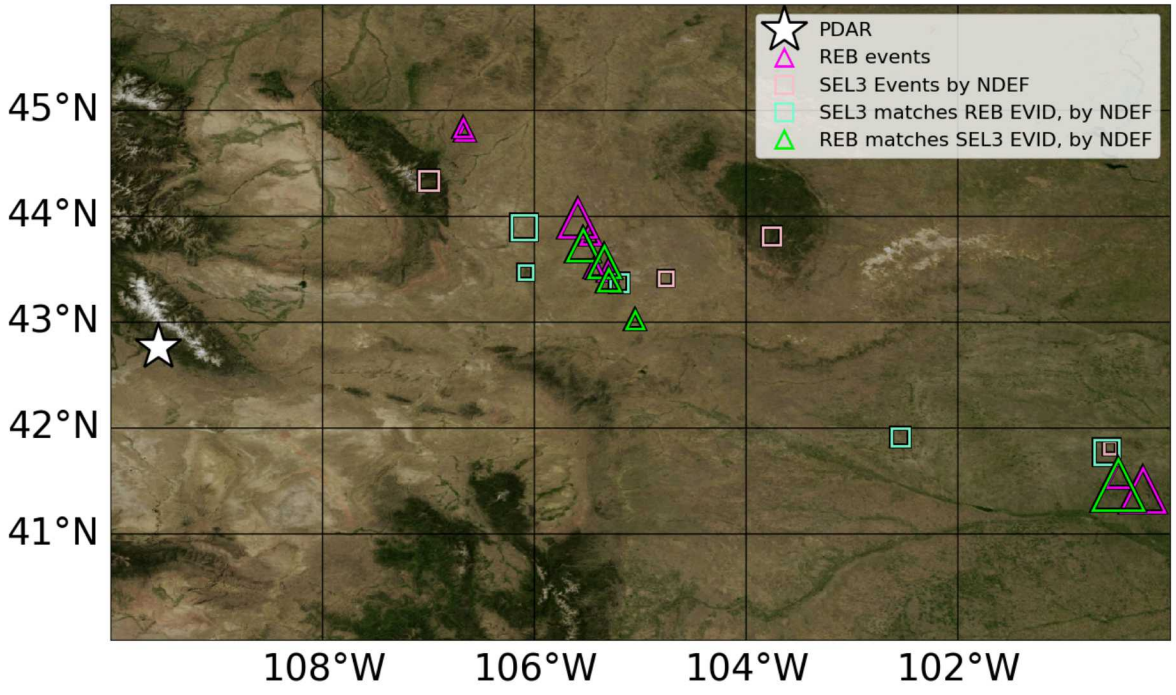


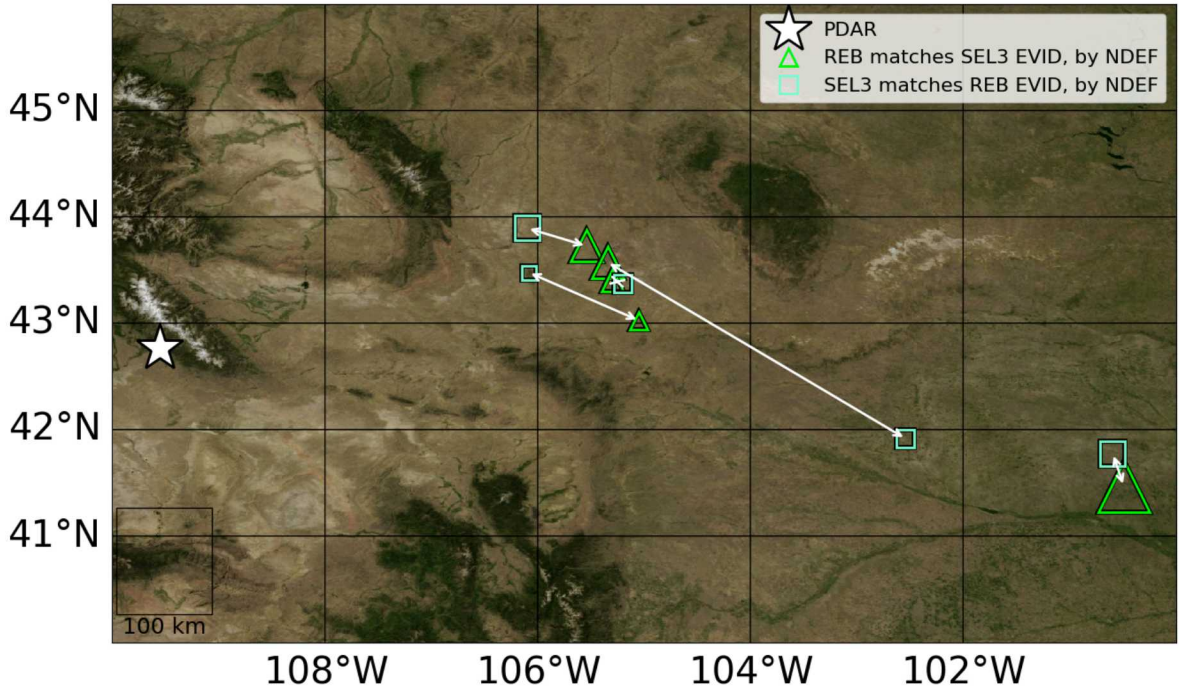
Wyoming Week 1 (4/4/2018 – 4/11/2018)

Overview of existing bulletins

- 9 SEL3 events in region/week
- 5 SEL3 events accepted by analysts for REB
- 4 SEL3 events rejected by analysts
- 8 REB events added by analysts, not in SEL3
- 13 final REB events in region/week

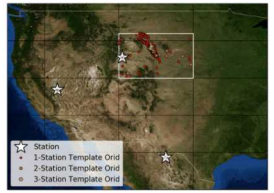


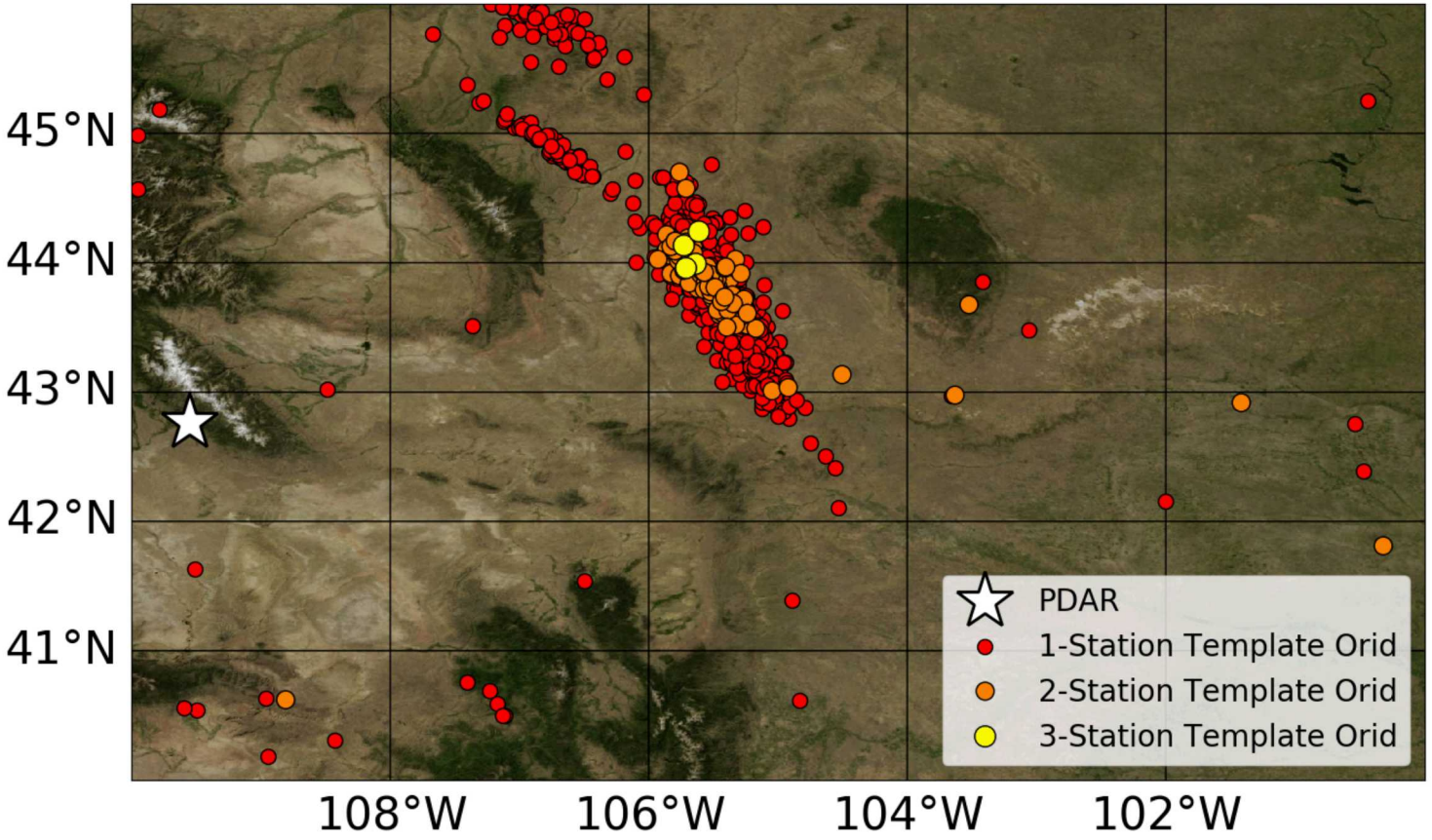




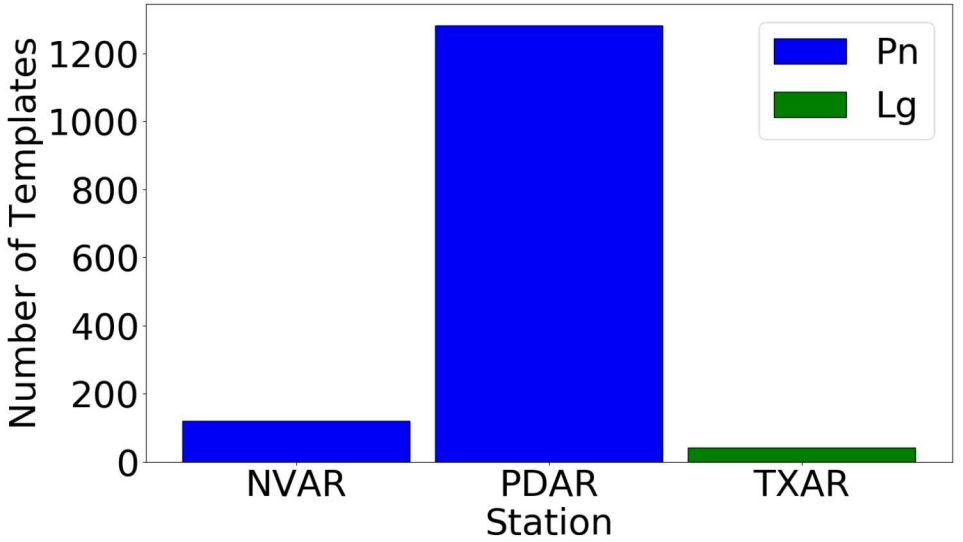
Wyoming Week 1 (4/4/2018 - 4/11/2018) Templates

Map of study area showing 1303 template locations by number of stations (1-3) from up to 10 years of REB events.

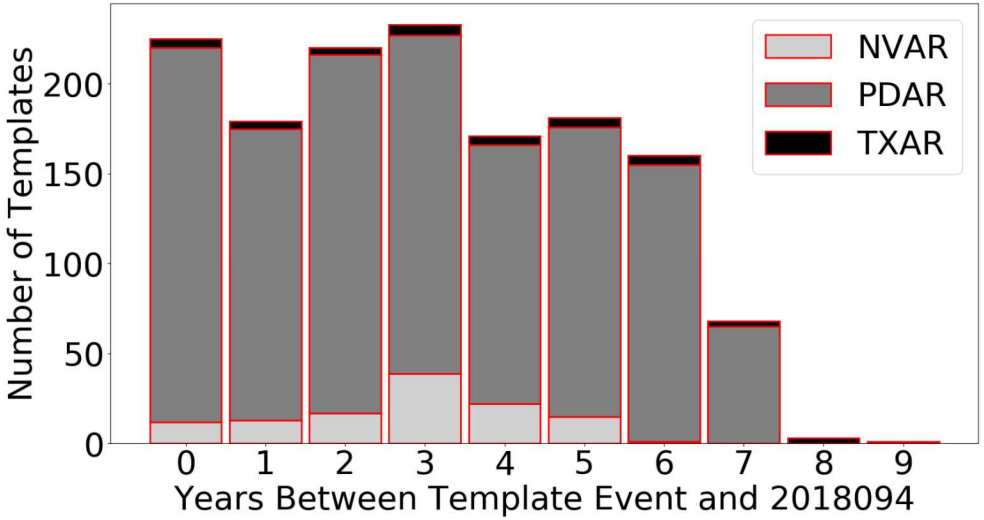




Number of templates by station

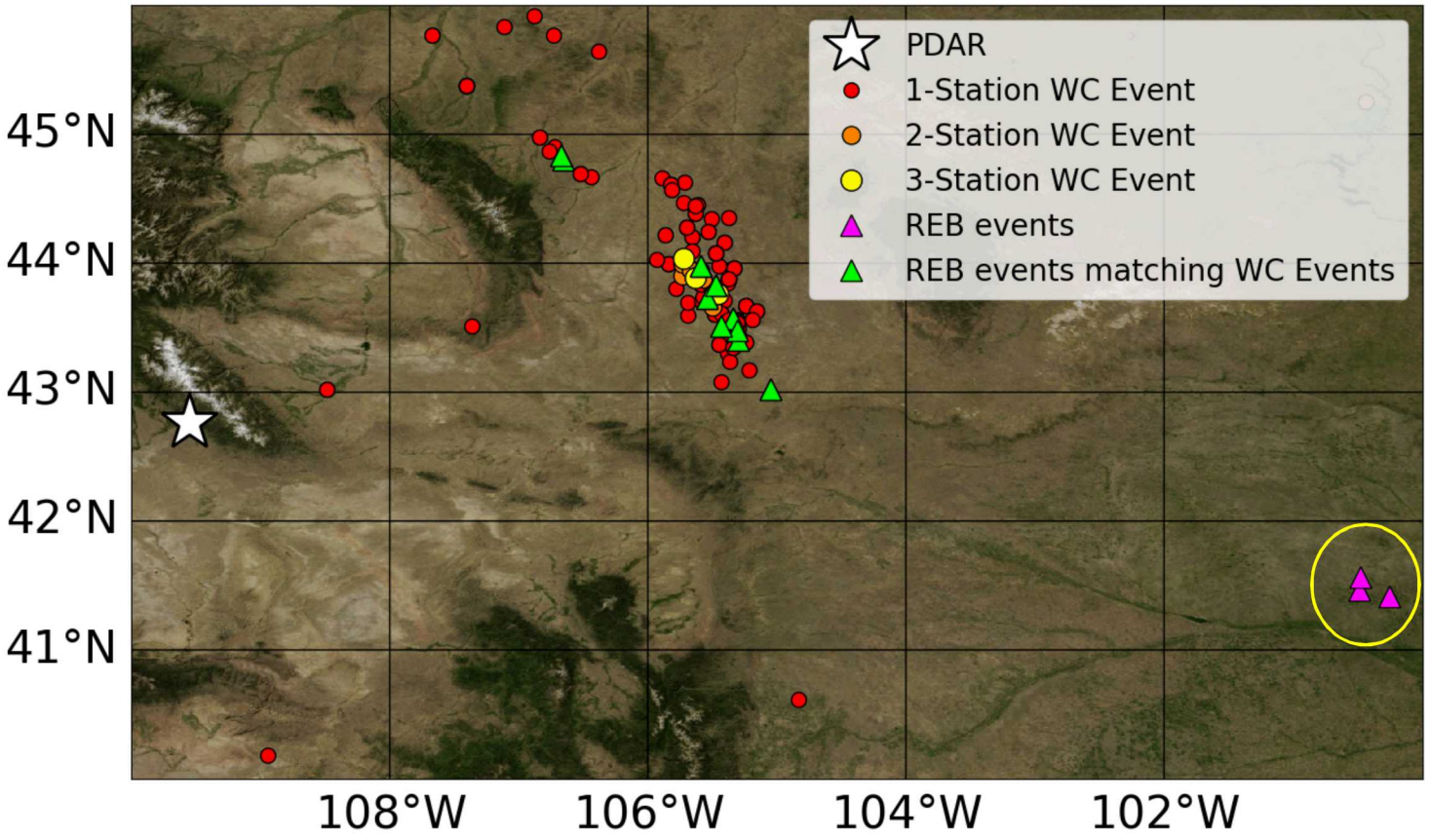


Age of templates (years) by station

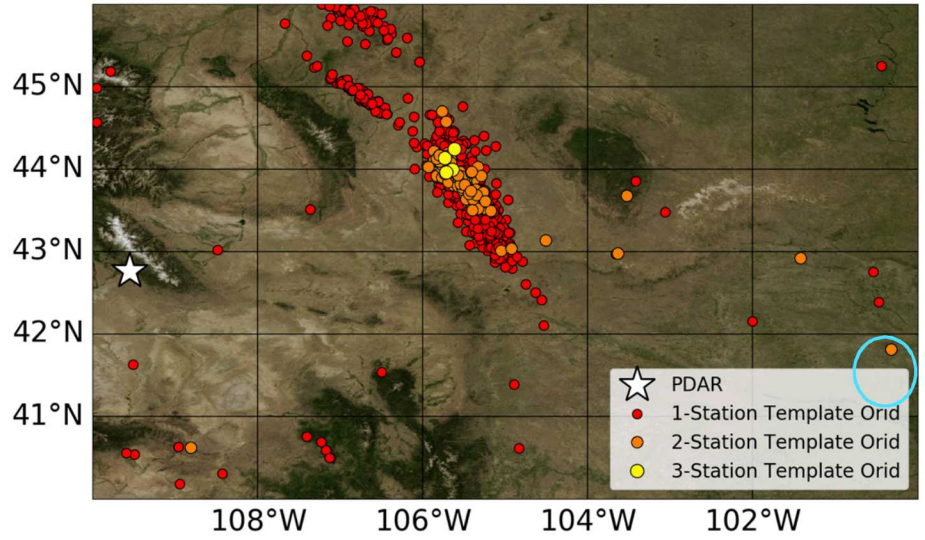


Wyoming Week 1 Waveform Correlation Events

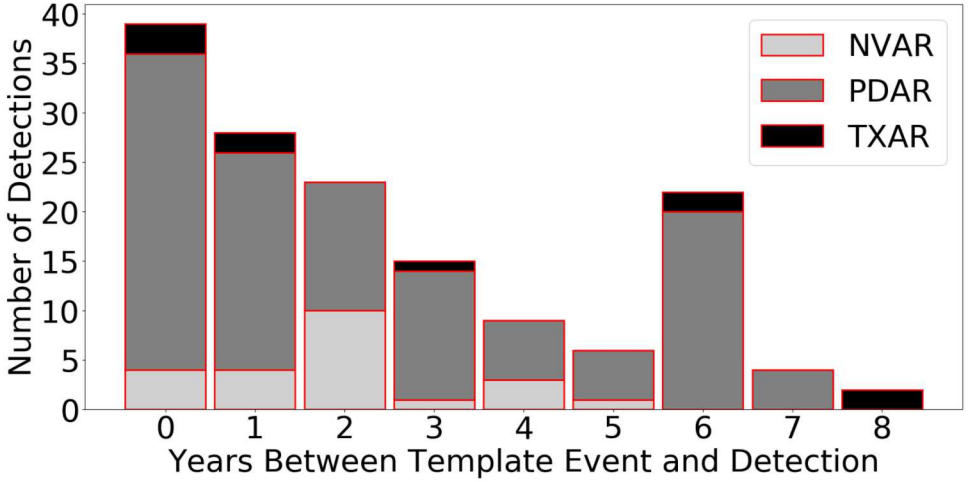
Map showing 136 waveform correlation and 13 REB event locations



Template Events near Missed REB events

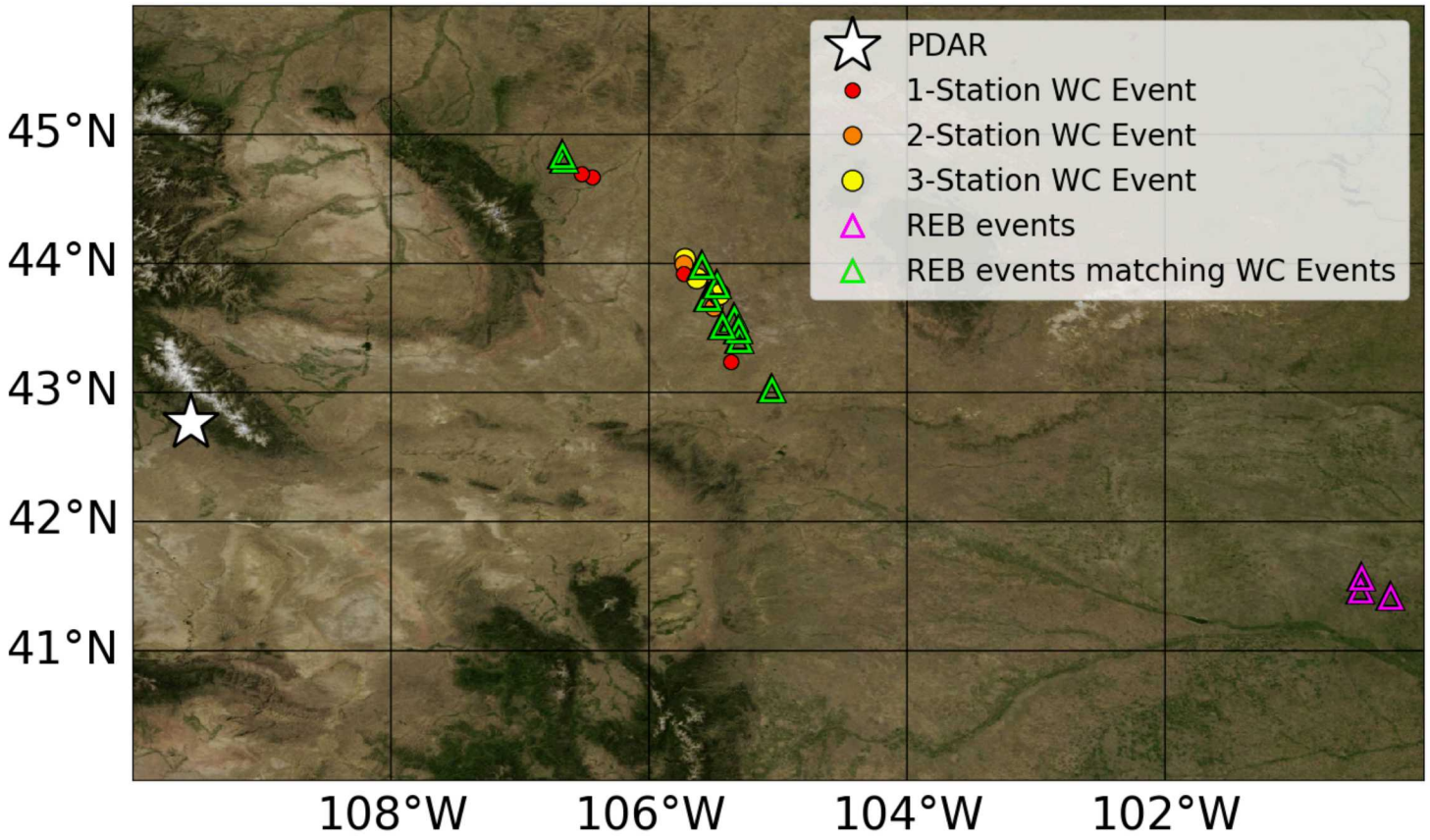


Age of detecting templates (years)

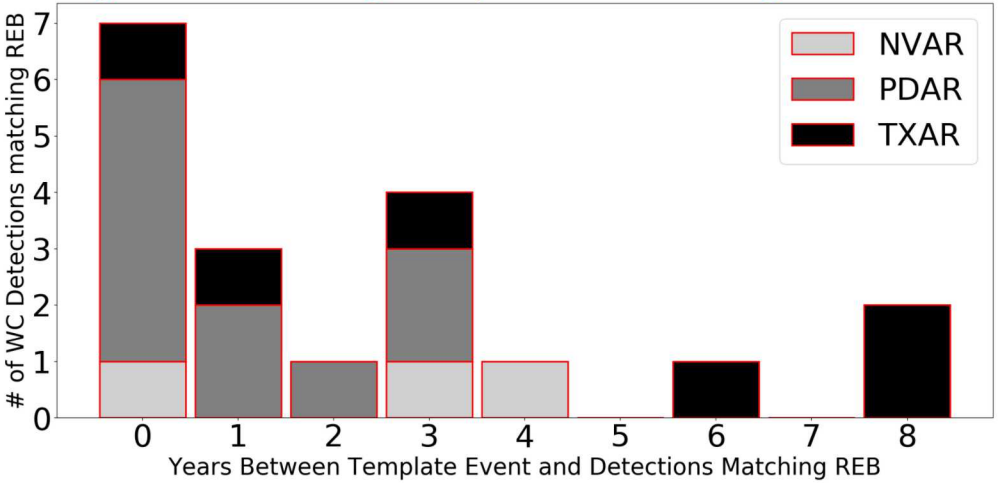


Wyoming Week 1 REB Event Matches

Map showing 13 REB event locations and
10 waveform correlation events within (1°, ±15s)

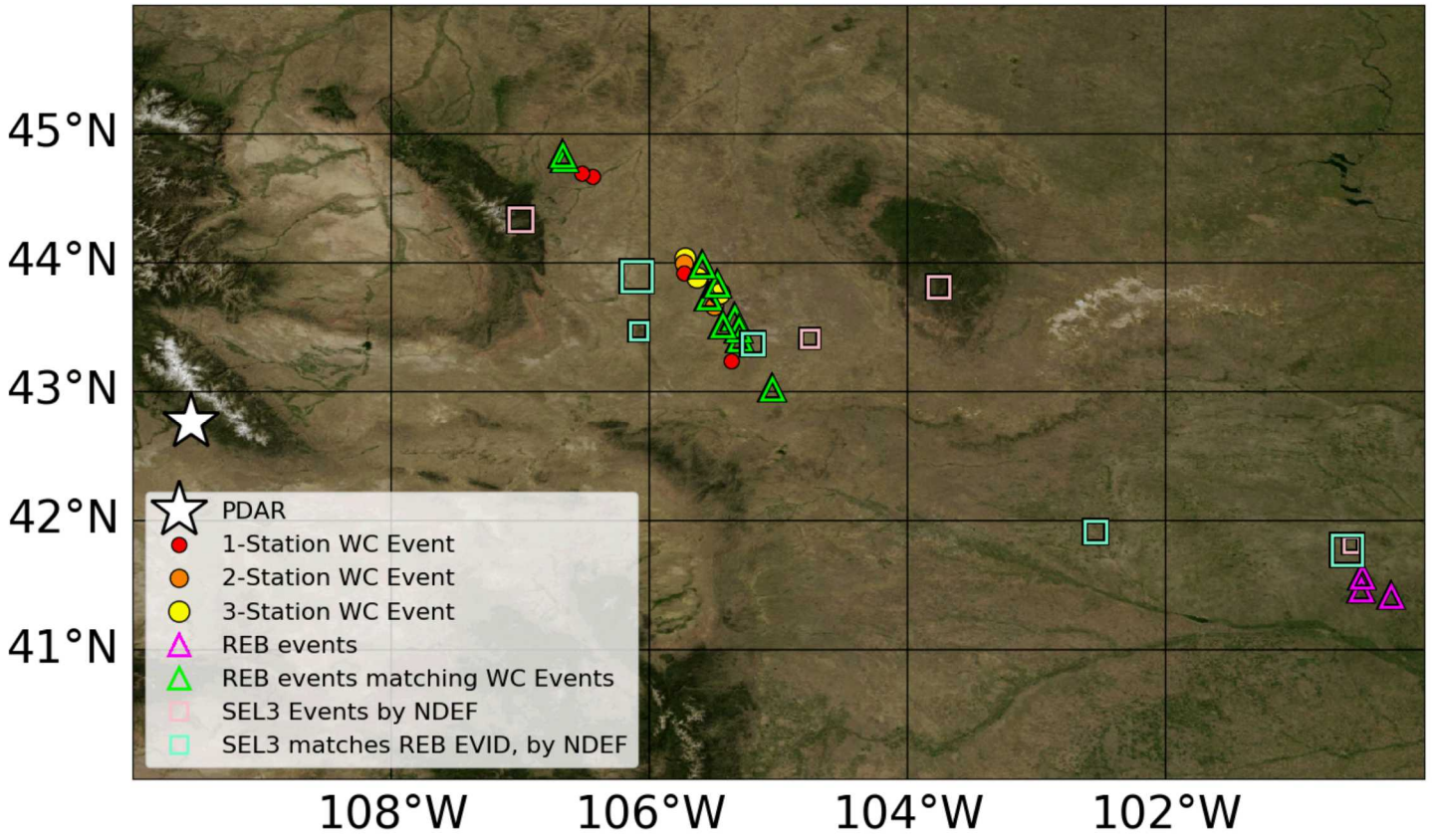


Age of detecting templates matching REB events



Wyoming Week 1 Comparing WC and SEL3 with REB Events

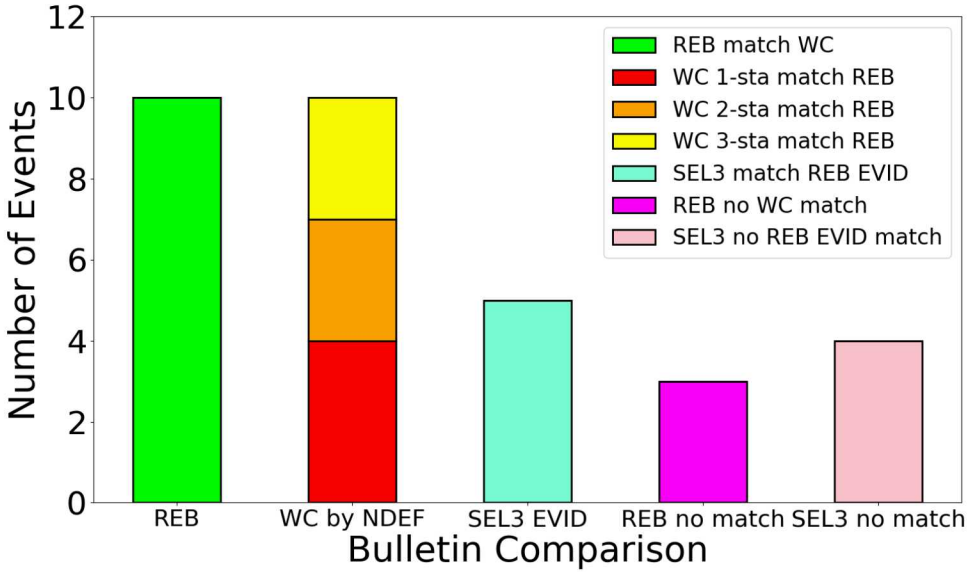
Map showing 13 REB events, 9 SEL3 events, and 10 waveform correlation events within (1°, ±15s)



Notes for Wyoming Week 1

- Waveform correlation locations are more accurate than SEL3
- Are the other 126 WC events valid?

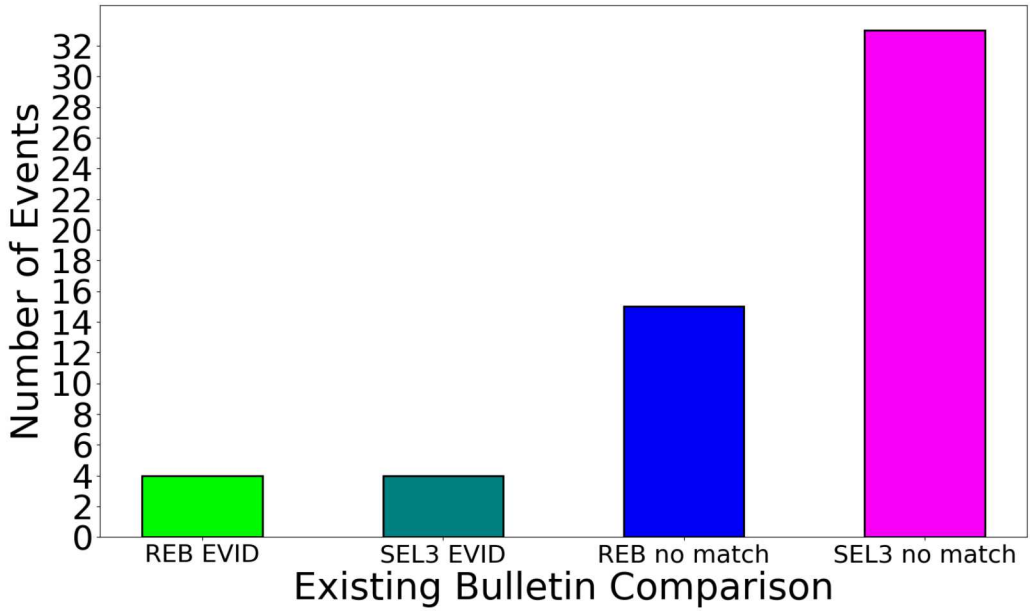
Bulletin Comparison for Wyoming Week 1

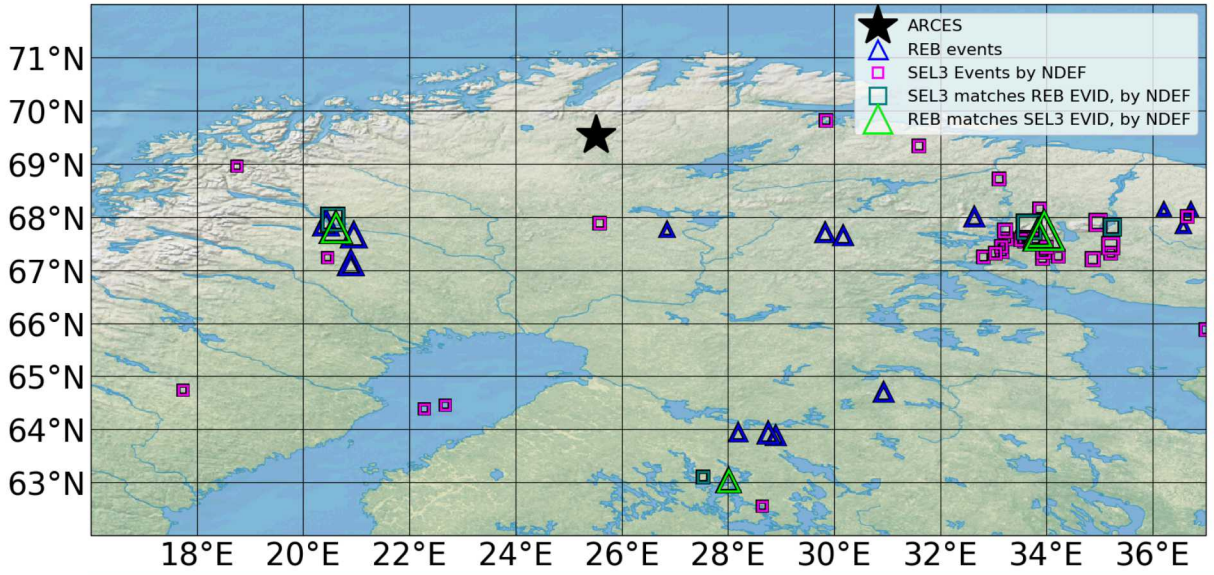


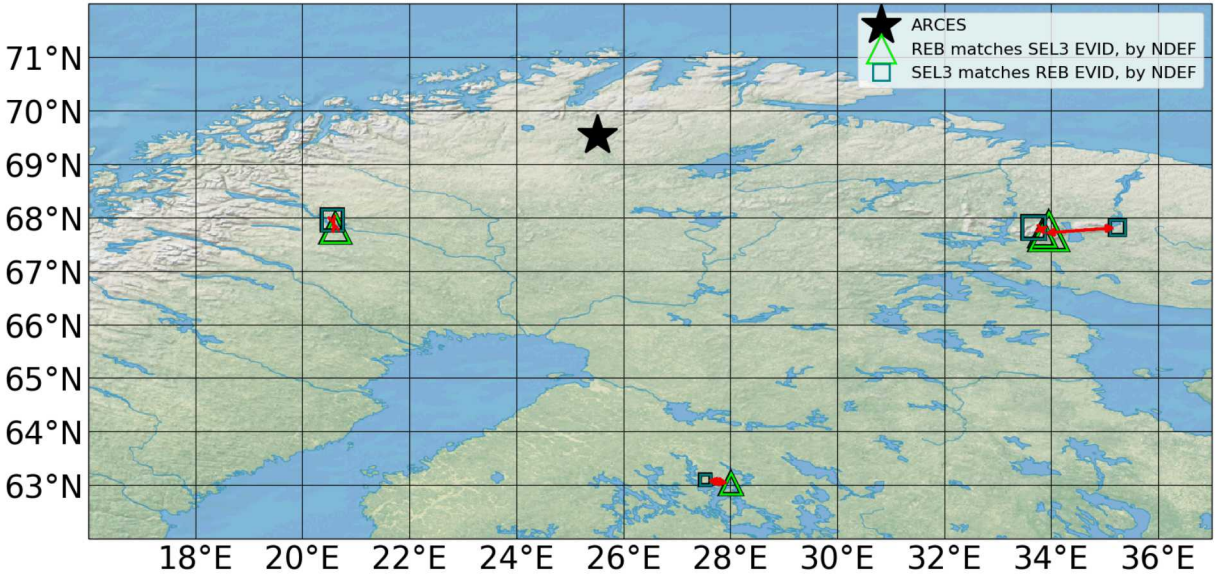
Scandinavia Week 1 (2/12/2018 – 2/18/2018)

Overview of existing catalogs

- 37 SEL3 events in region/week
- 4 SEL3 events accepted by analysts for REB
- 33 SEL3 events rejected by analysts
- 15 REB events added by analysts, not in SEL3
- 19 REB Events in region/week

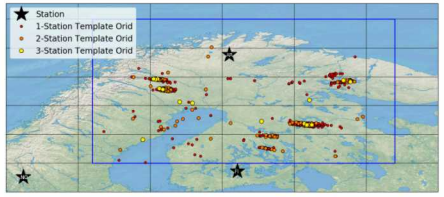


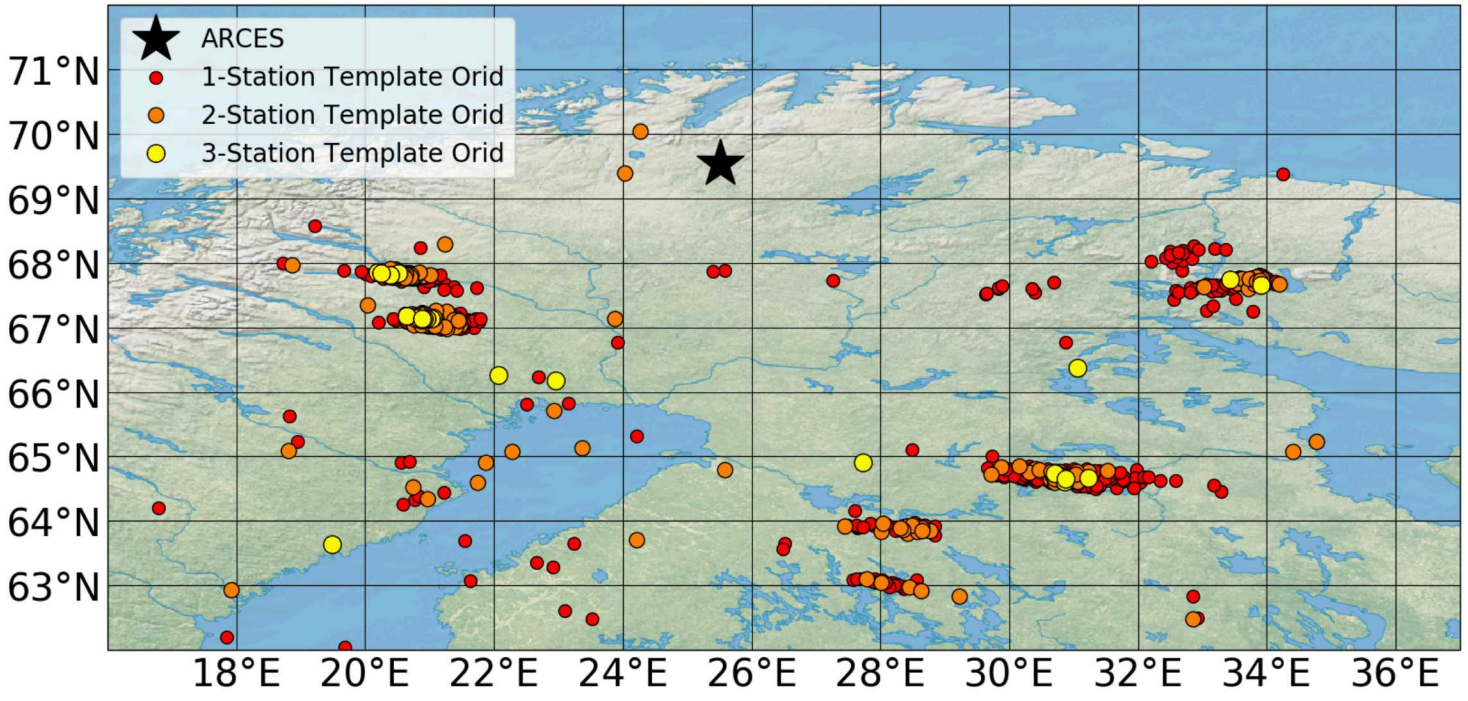




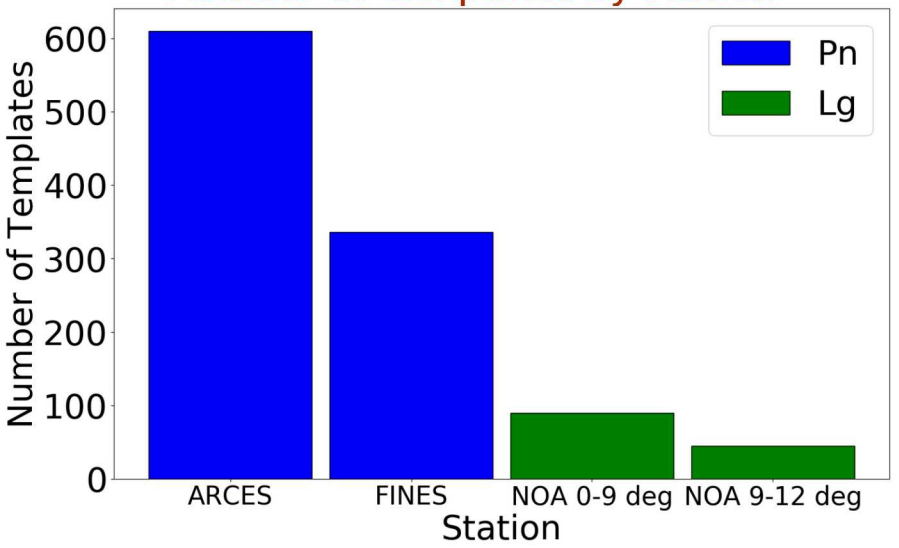
Scandinavia Week 1 (2/12/2018 - 2/18/2018) Templates

Map of study area showing 970 template origin locations by number of stations (1-3) from up to 10 years of REB events.

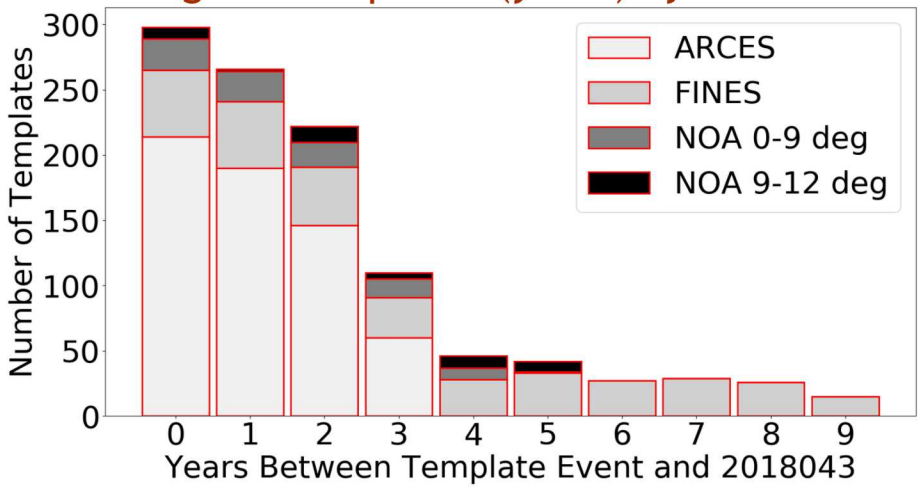




Number of templates by station

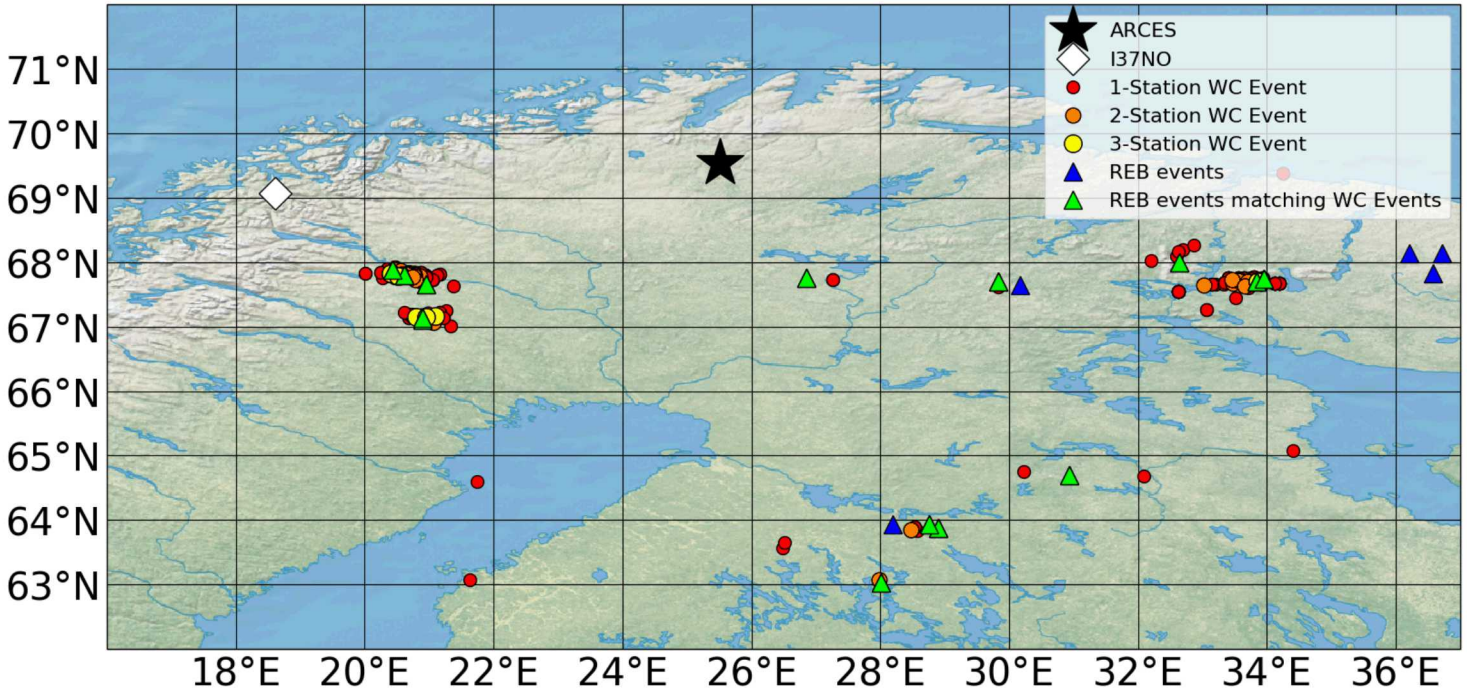


Age of templates (years) by station

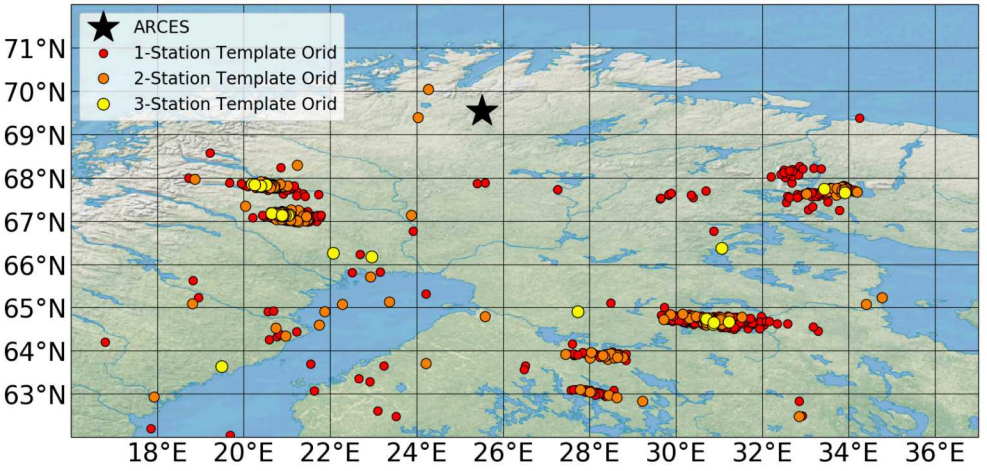


Scandinavia Week 1 Waveform Correlation Events

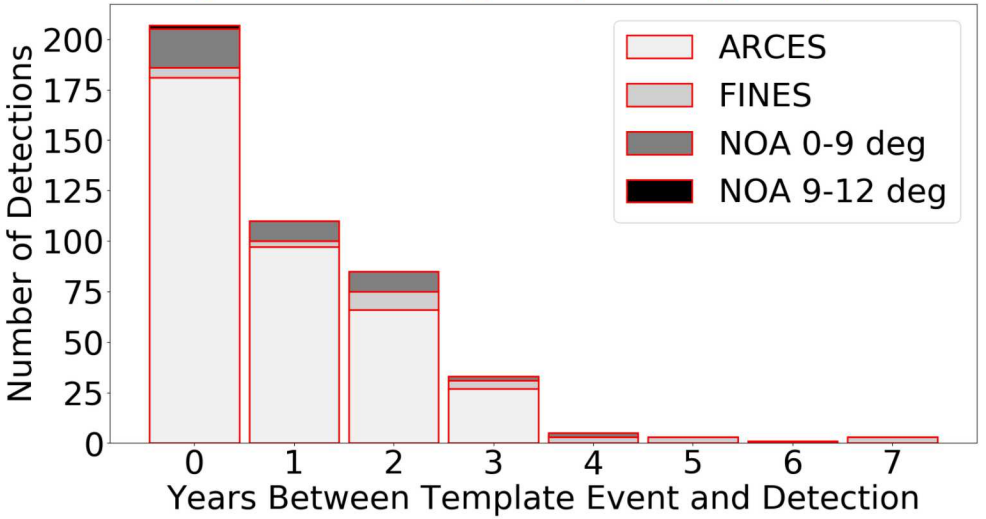
Map showing 390 waveform correlation and 19 REB event locations.



Template Events

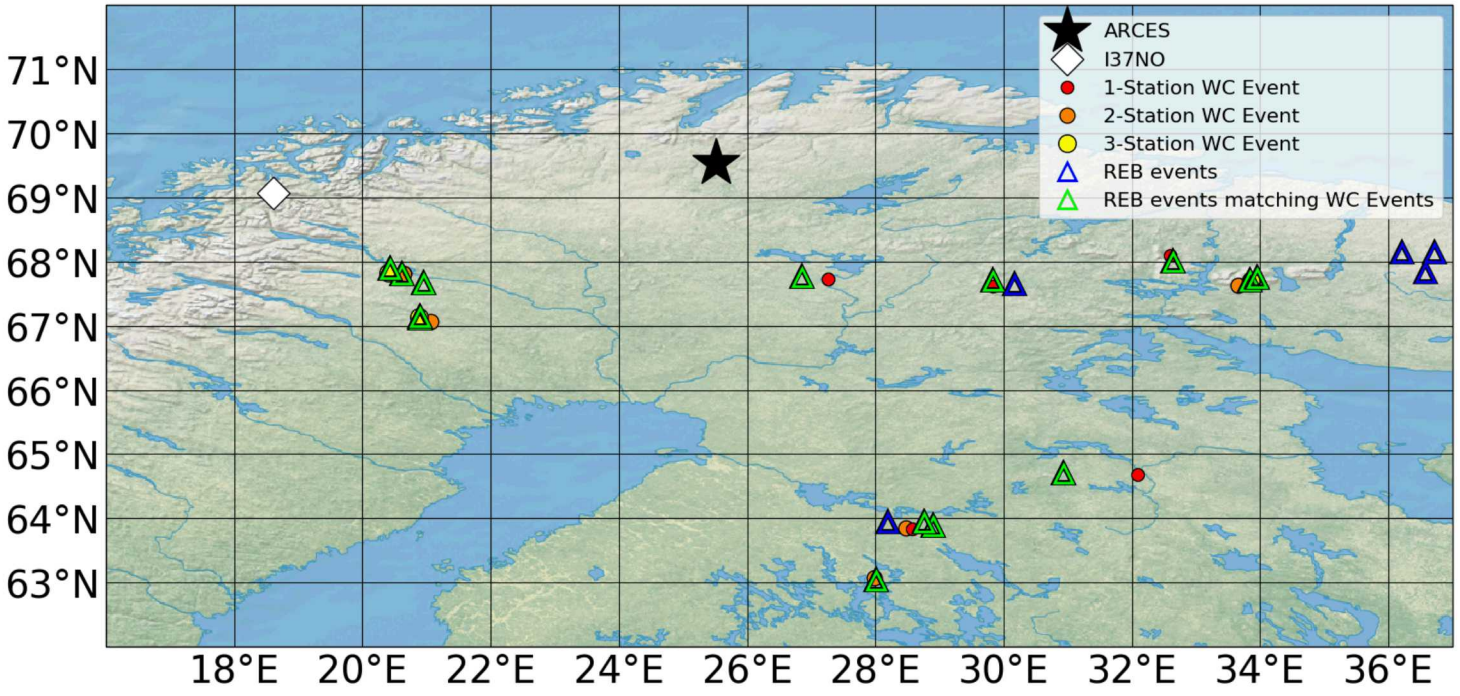


Age of detecting templates (years)

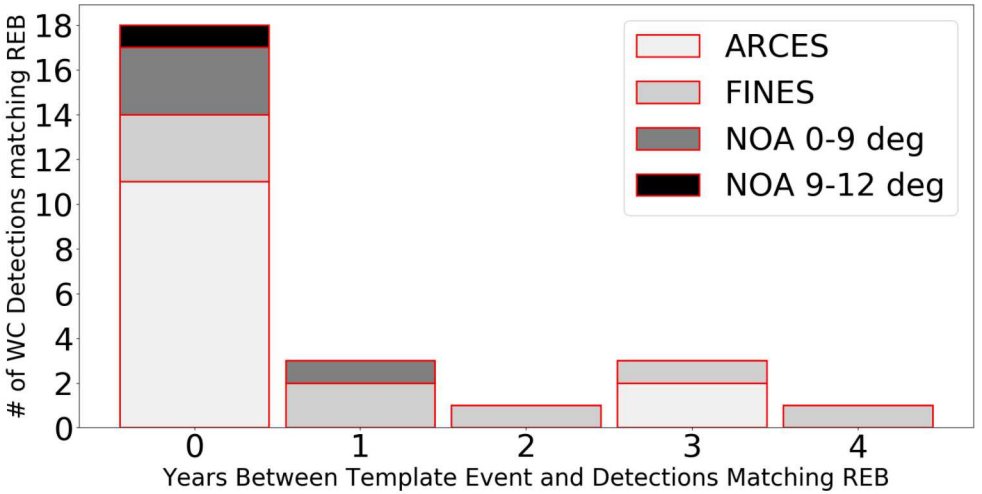


Scandinavia Week 1 REB Event Matches

Map showing 19 REB event locations and
14 waveform correlation events within (1°, ±15s)

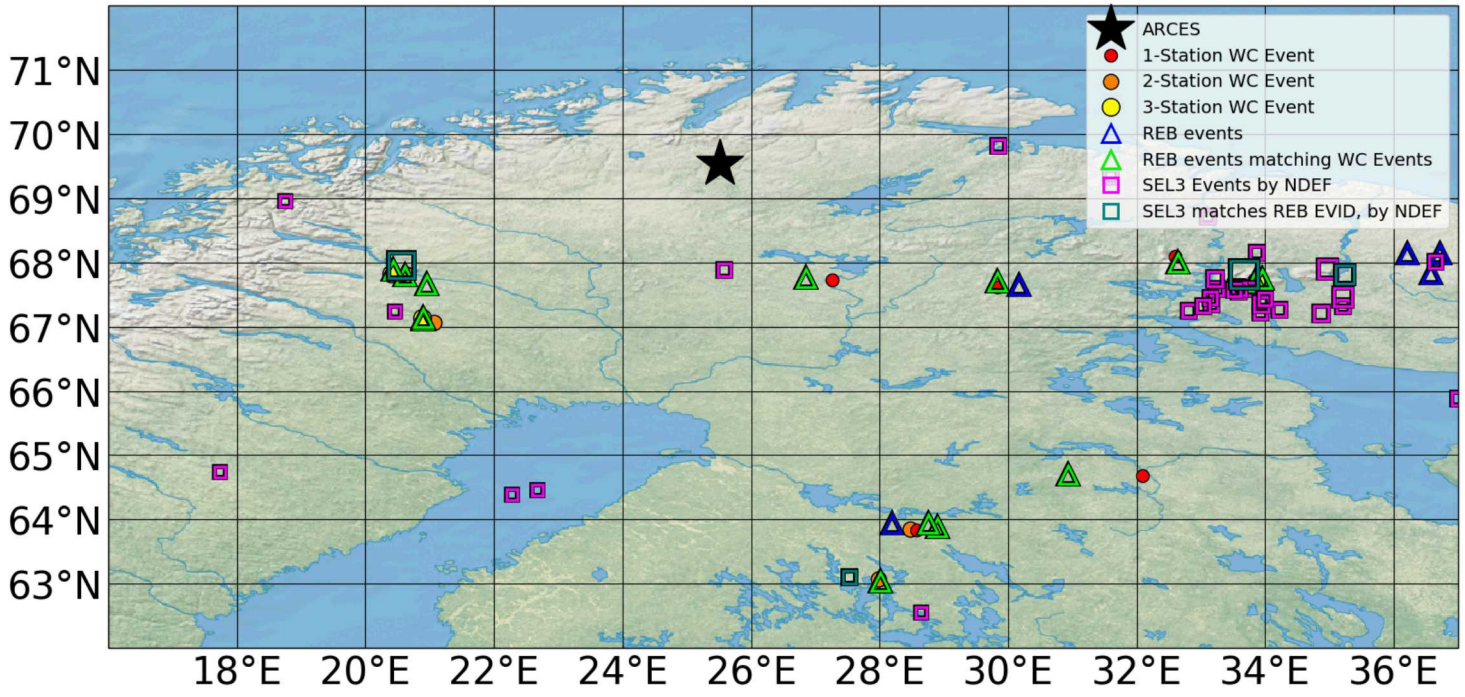


Age of detecting templates matching REB events



Scandinavia Week 1 Comparing WC and SEL3 with REB Events

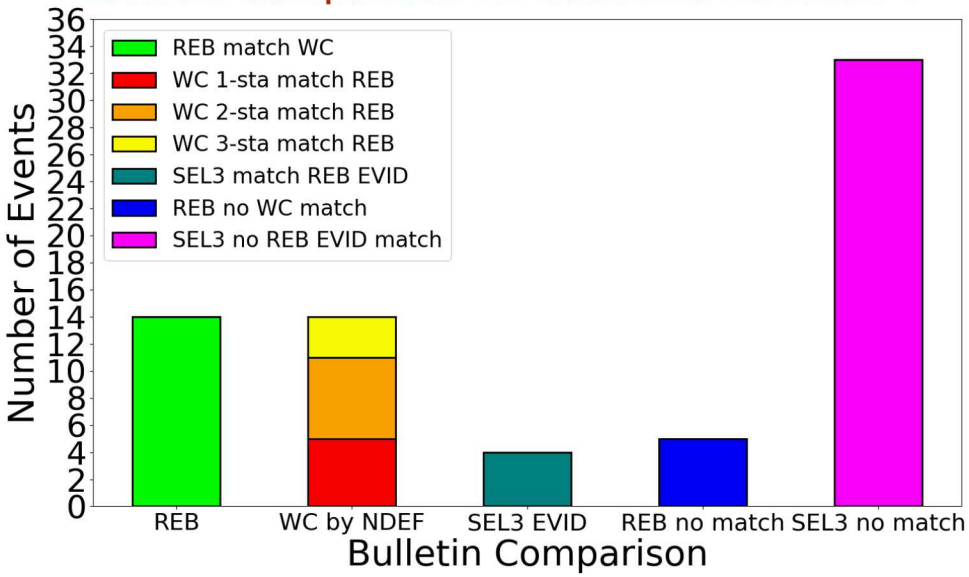
Map showing 19 REB events, 37 SEL3 events, and 14 waveform correlation events within (1°, ±15s)



Notes for Scandinavia Week 1

- Many events from SEL3 were discarded and/or relocated

Bulletin Comparison for Scandinavia Week 1



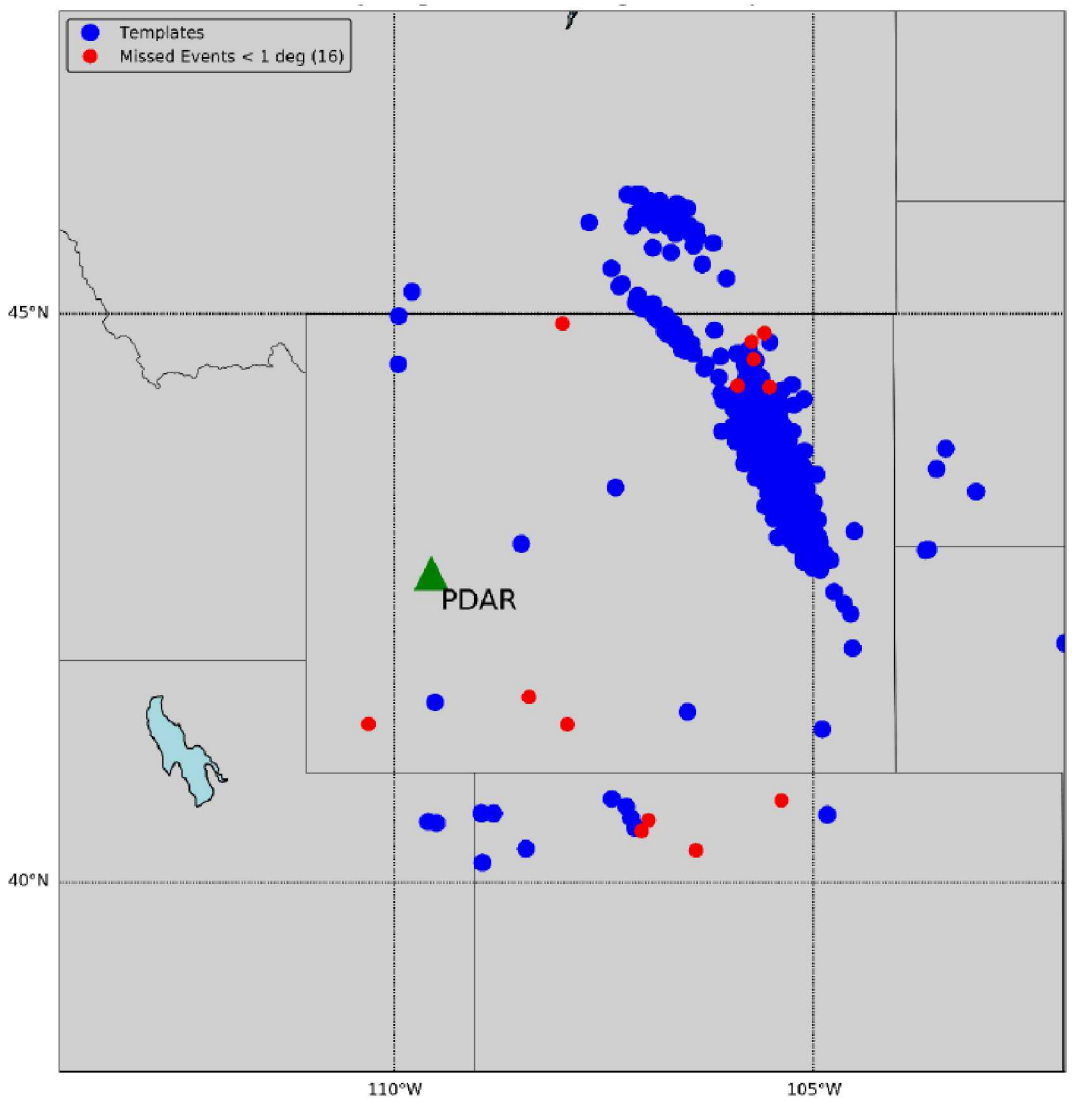
Expert Analyst Review

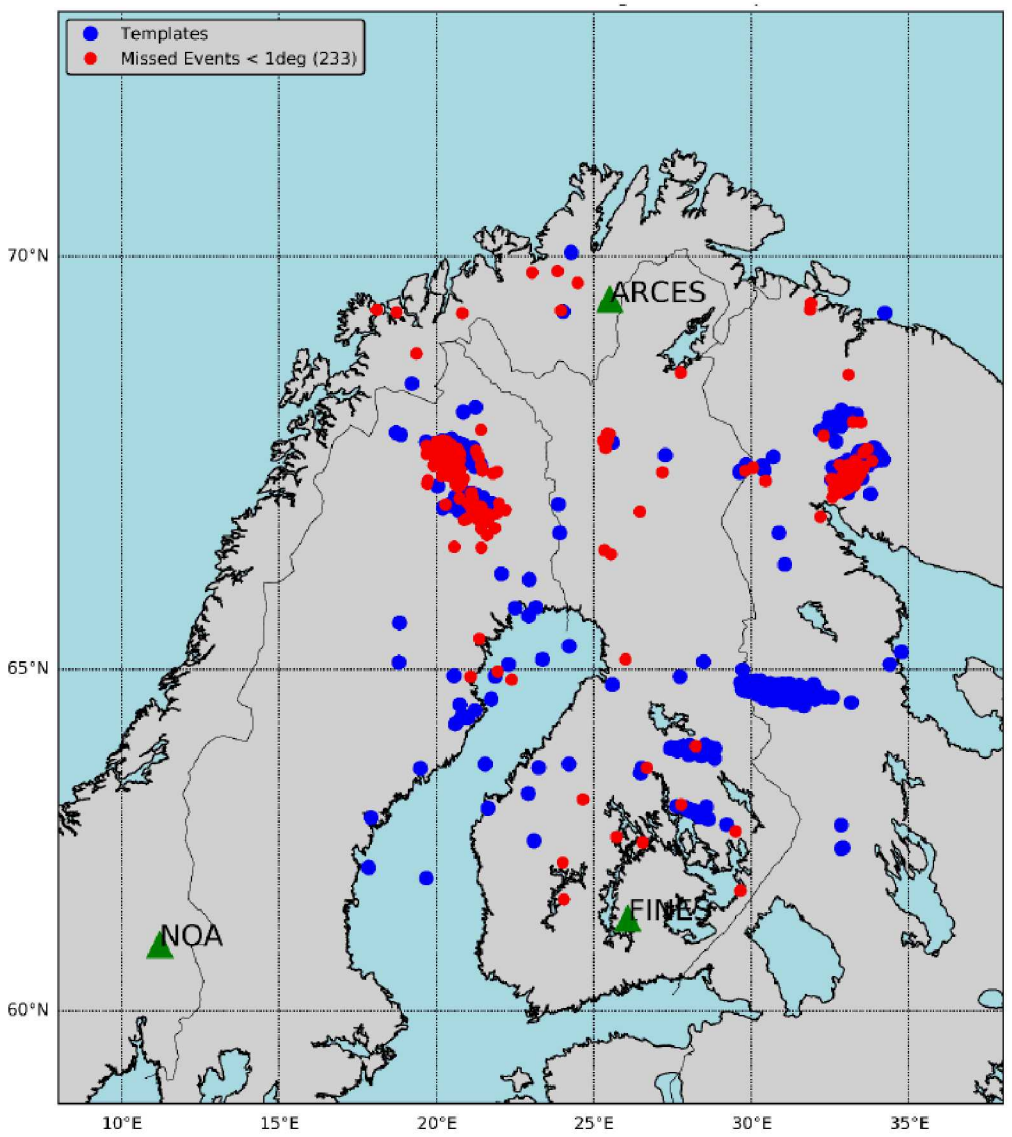
- Waveform correlation can detect real events that do not meet REB criteria.
- We need an accurate count of total real events to evaluate the method.
- Expert analyst, Chip Brogan, visually inspected all the SeisCorr events.

Region	# SeisCorr Events	True Positives	False Positives	False Negatives (Missed Events)
Wyoming, USA	136	106	30	16
Scandinavia	390	371	19	233

- False positives are SeisCorr events not confirmed by analyst review.
- Missed events are legitimate events found by analyst within 1 degree of a template.
- Our expert analyst recommended trying a narrower filter band for the Scandinavia region to detect more of the missed events.

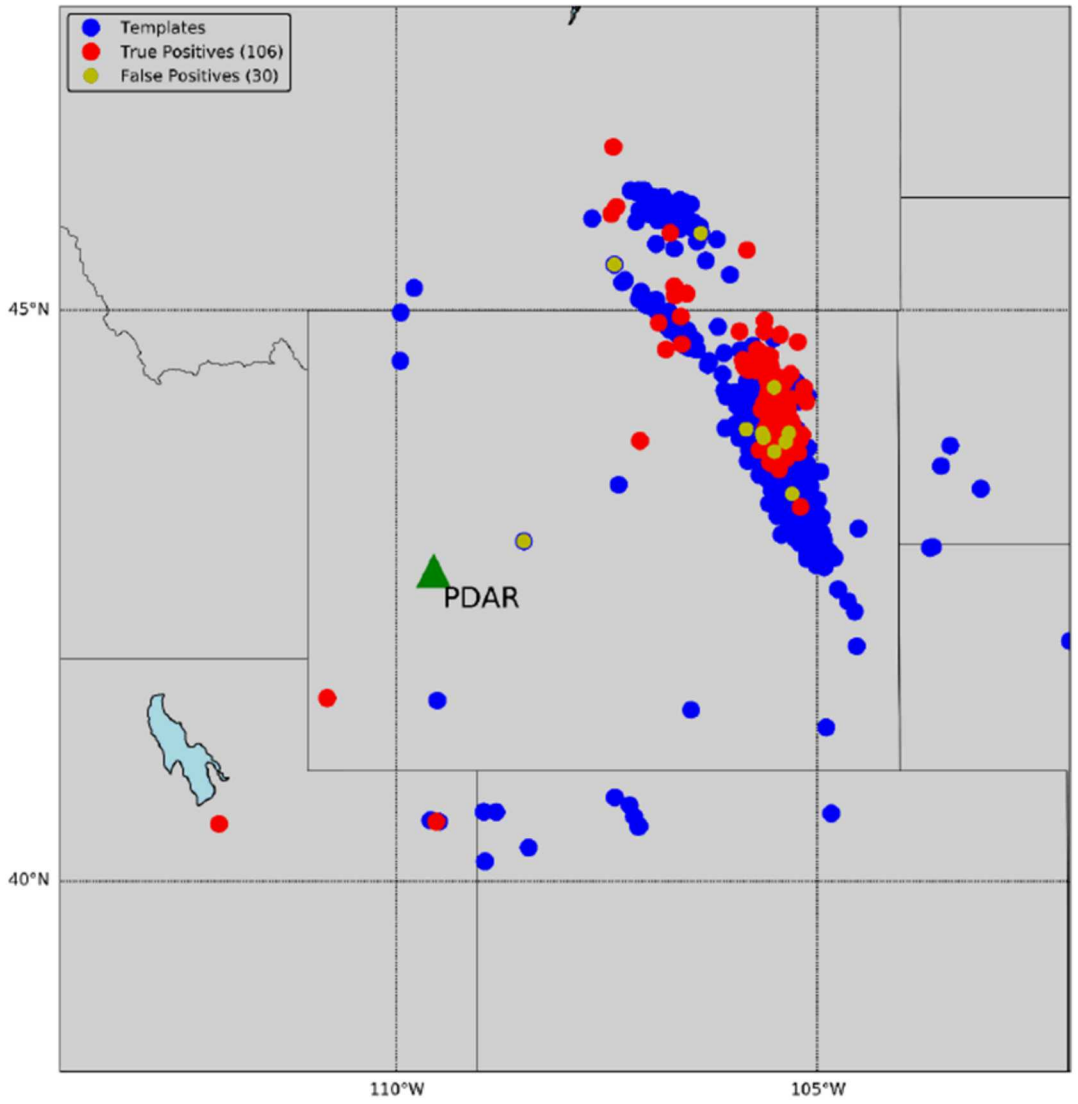
Locations of Templates and Missed Events*

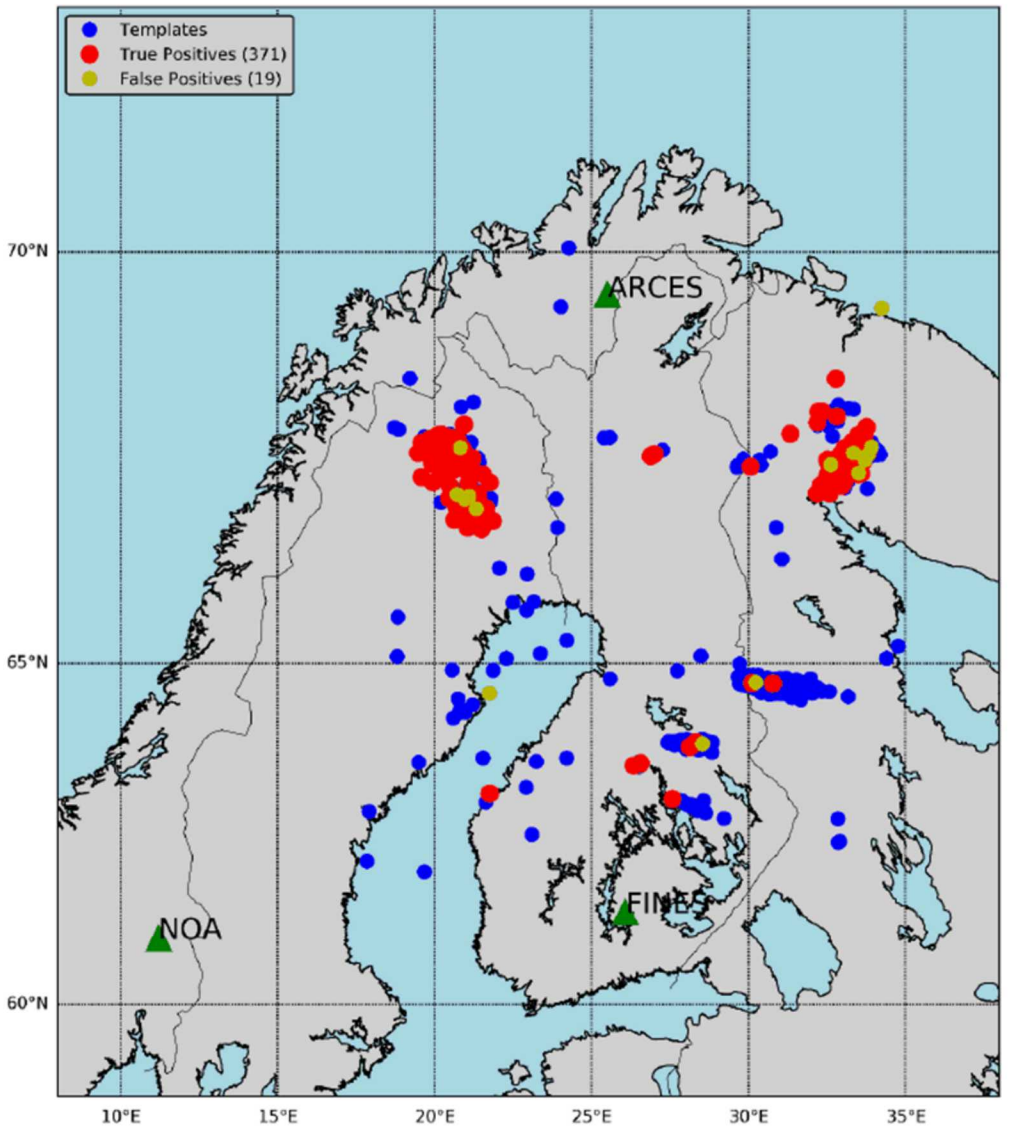




*Missed Events are counted if event location is within 1 degree of template location.

Locations of Templates and False Positives*





*The false detections are single-station events.

Conclusions

- Results indicate that waveform correlation will improve the effectiveness of the IDC pipeline by:
  - detecting many REB events that are currently being missed by SEL3, and
  - providing better locations, which should require less refinement by the analysts.
- Using long duration templates for close stations yields good results.
- Due to the sparseness of the IMS network and the small size of mining explosions, many historical events only have good templates at one station.
  - We allowed single station WC detections to take better advantage of the archive.
  - While our past work suggests that single station WC detections may include false events, expert analyst review found most WC detections were true events in this study.
- Waveform correlation finds a large percentage of REB events, but also generates many additional events, which may require analyst effort to review.

References

Sundermier, A., R. Tibi, and C. J. Young (2020). Applying Waveform Correlation to Mining Blasts Using a Global Sparse Network, *Technical Report SAND2020-7660*.

Sundermier, A., R. Tibi, R. A. Brogan, and C. J. Young. Applying Waveform Correlation to Reduce Seismic Analyst Workload due to Repeating Mining Blasts. *In preparation for publication*.