CTBT:
SCIENCE AND
TECHNOLOGY
2017 CONFERENCE

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PTS

Assessing the consistency, quality, and completeness of the Reviewed Event Bulleting with waveform cross correlation

Outline

- Motivation
- Spot check at the IDC
- Reviewed Event Bulletin
- Waveform cross correlation
- Correlation of historical events: best master events
- Testing REB events
- Testing REB detections
- Testing non-detections
- During interactive analysis

Spot check at the IDC

Extended interactive analysis of specific data sets by experienced analysts with routine and expert software without tight time constraints

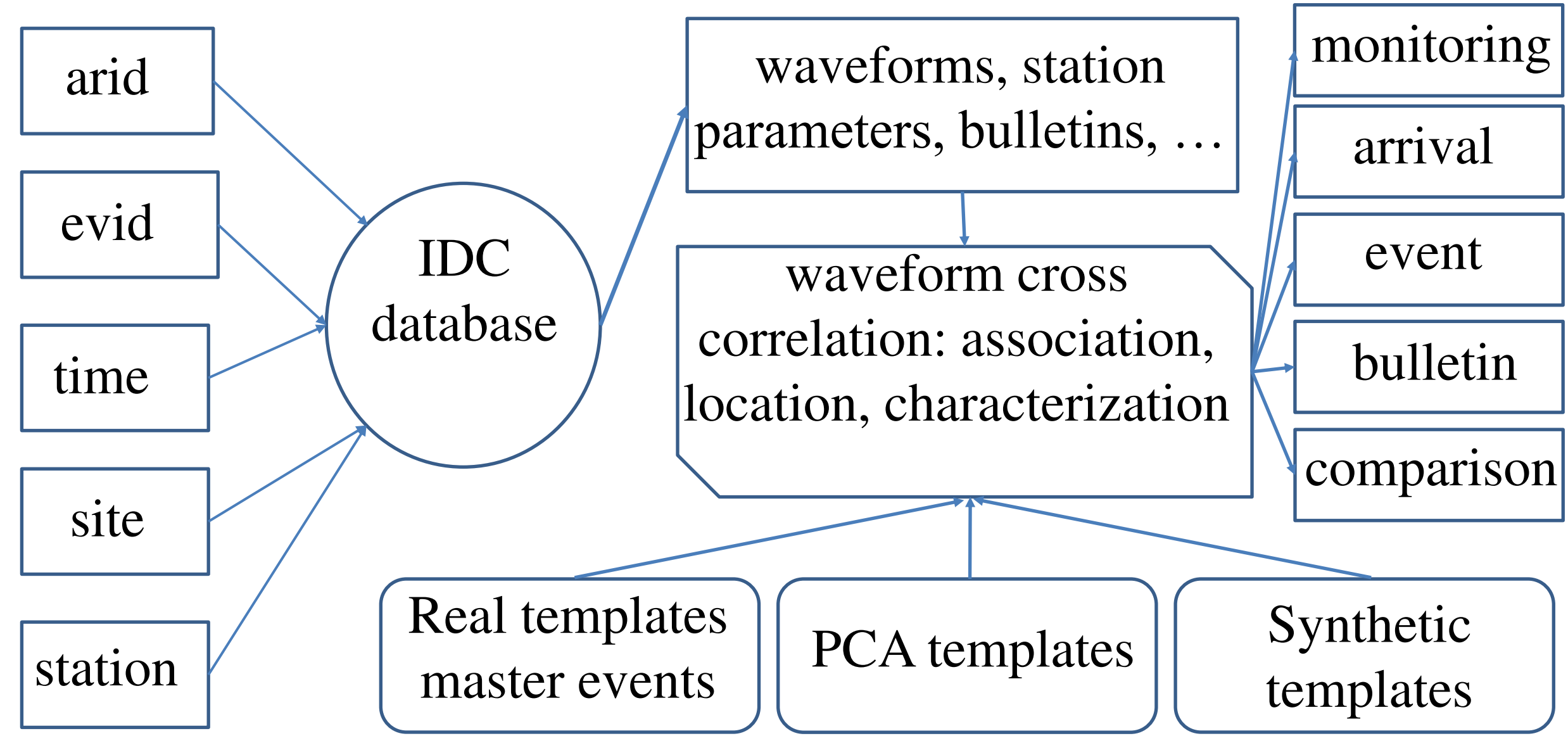
Goals: quality, consistency, completeness

Extensive human recourses are needed

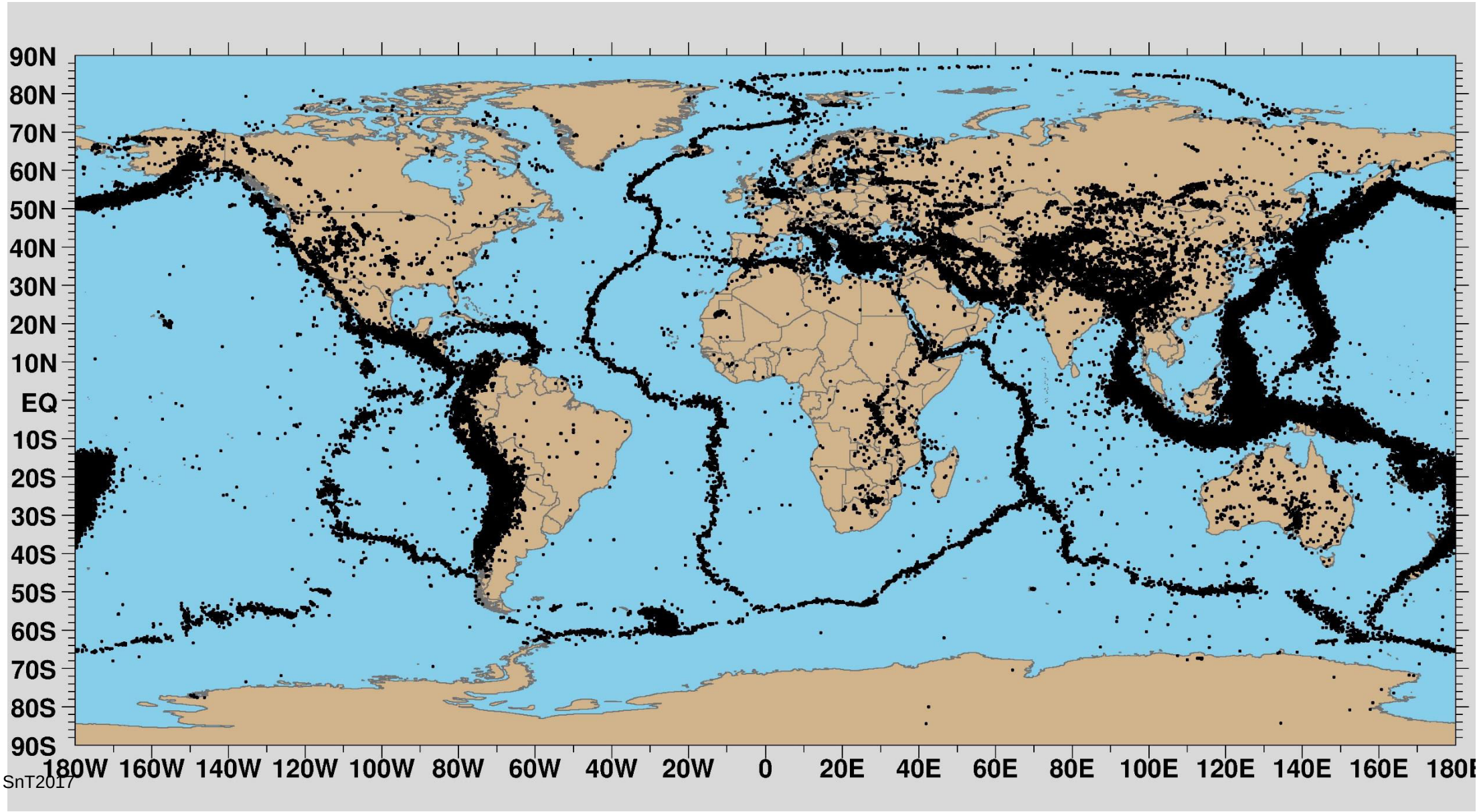
Motivation

1. To quantify the level of similarity between signals from close events and its dependence on magnitude and distance
2. To assess the consistency, quality, and completeness of the Reviewed Event Bulletin
3. To develop a tool for automatic and interactive check of signals and events using a set of best Master Events
4. To evaluate noise reduction by the Principal Component Analysis

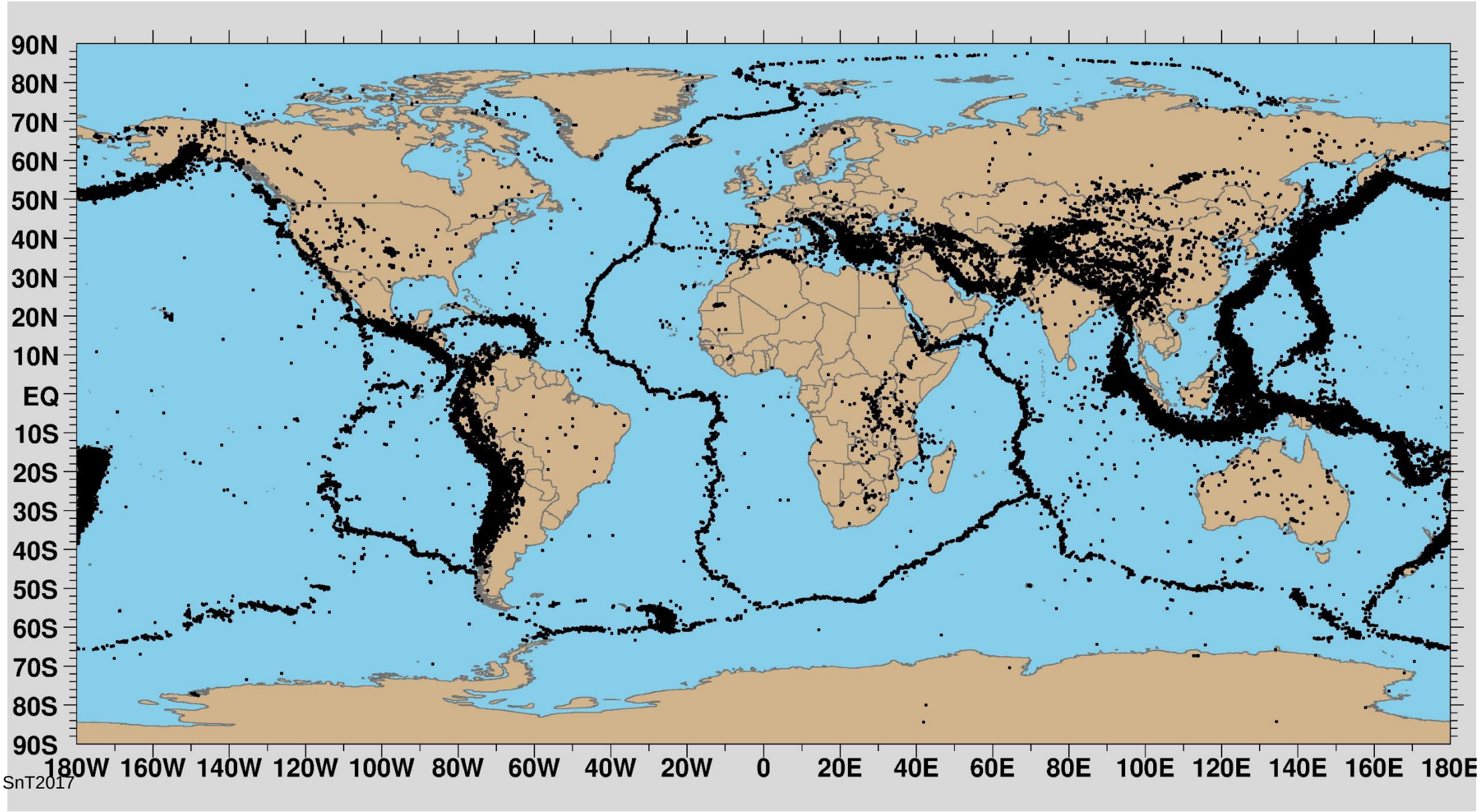
Spot check using waveform cross correlation



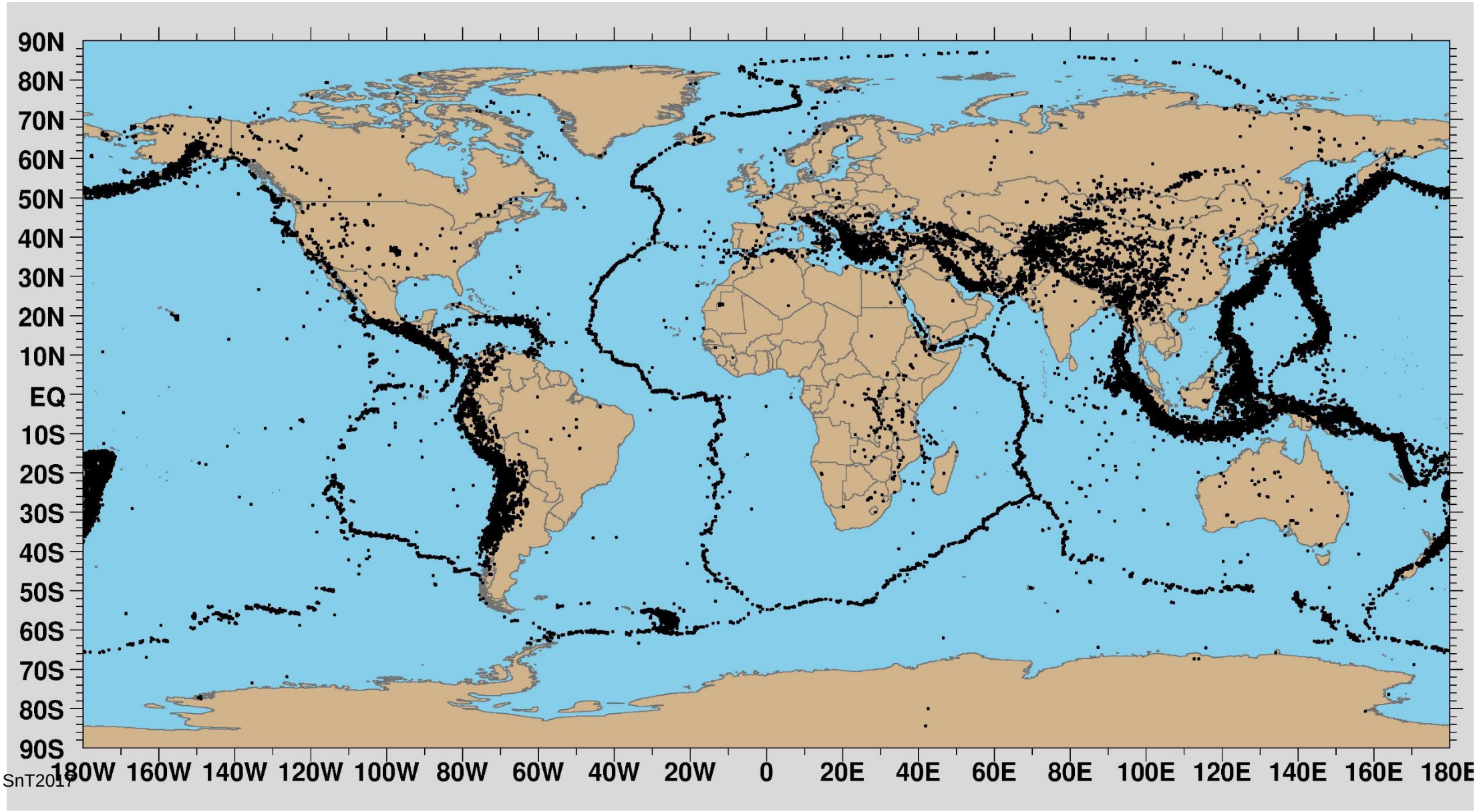
All REB events (~270,000 since May 2010)



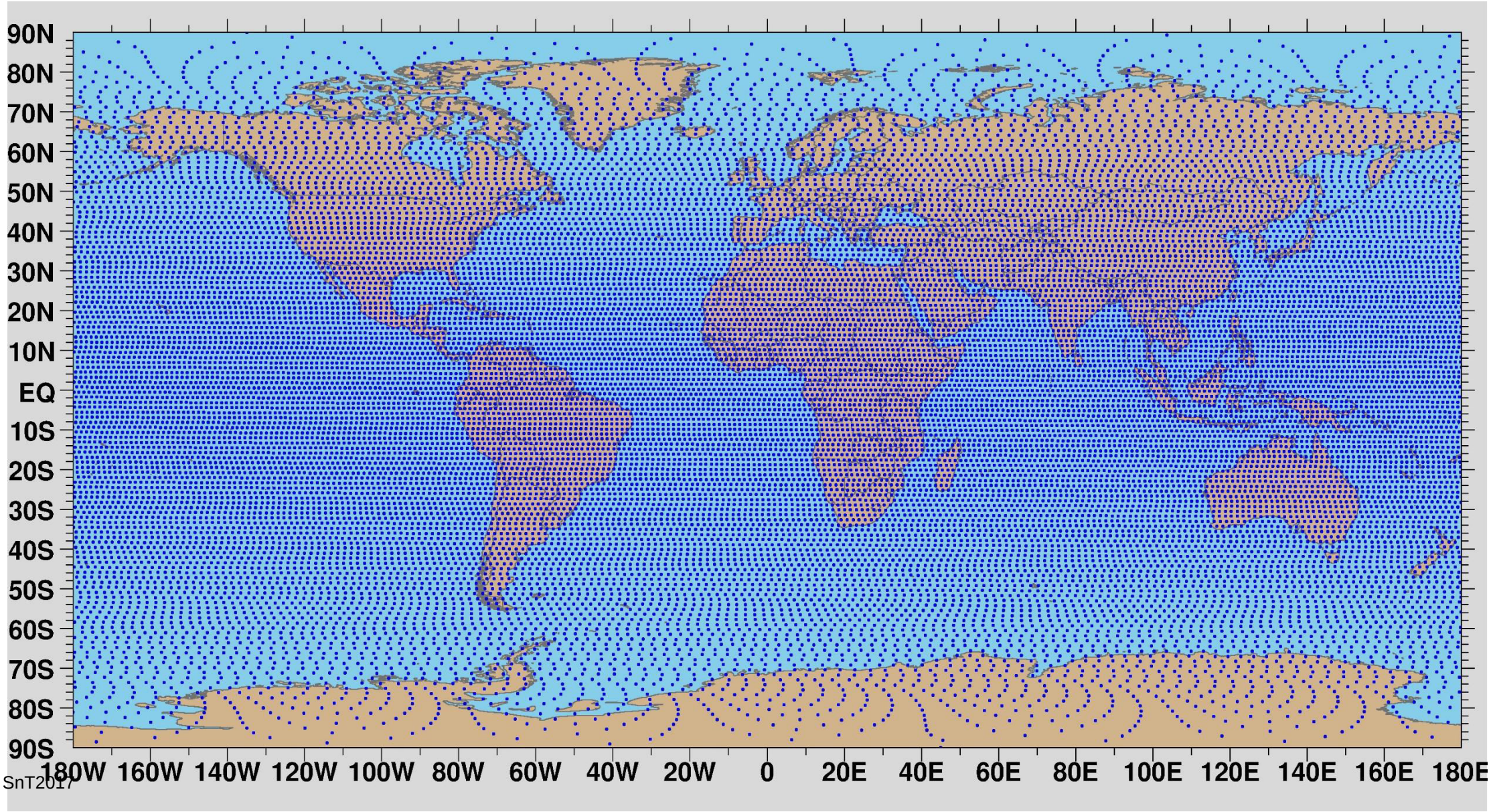
REB events with ndef>6 (~150,000)



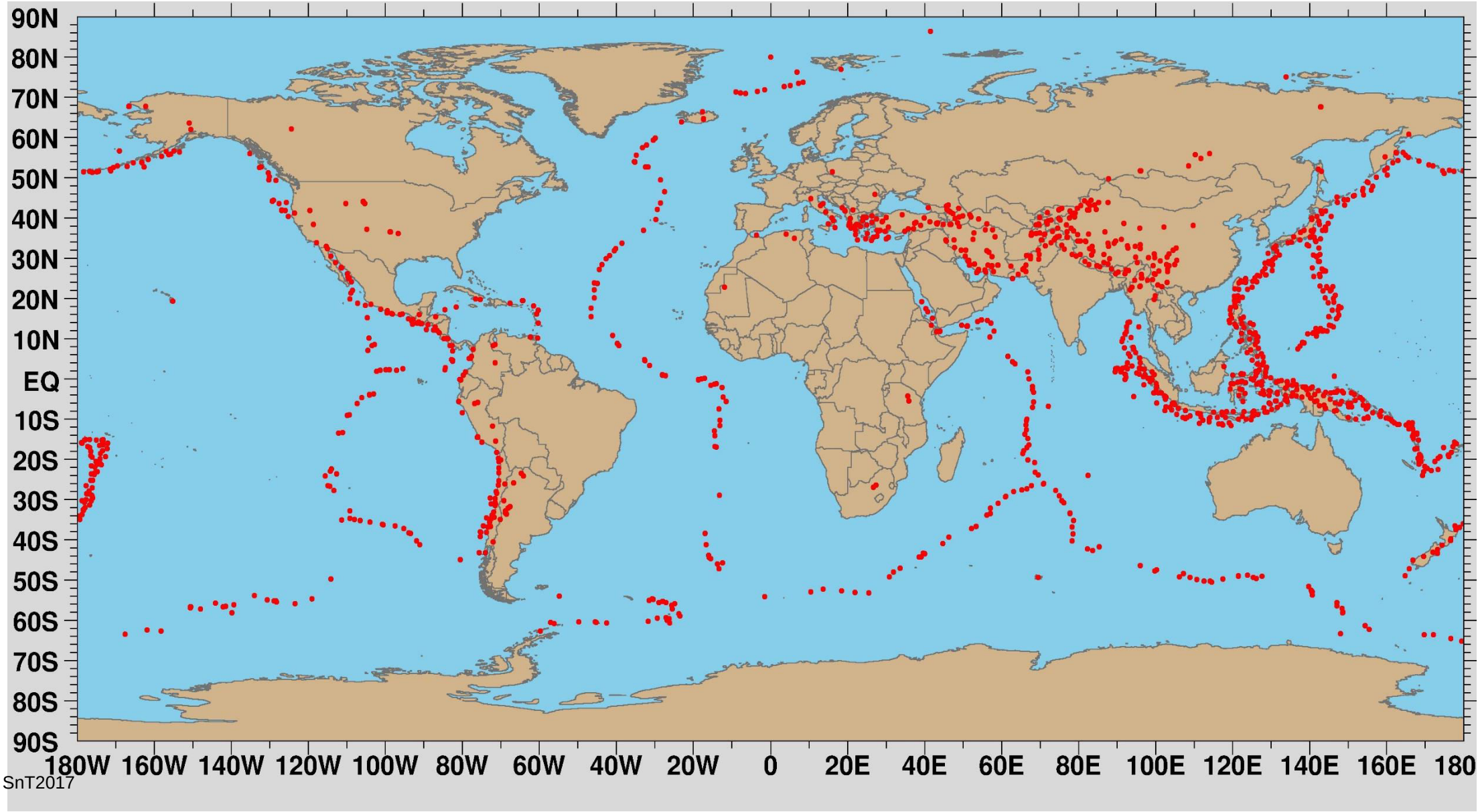
REB events with good quality (~85,000)



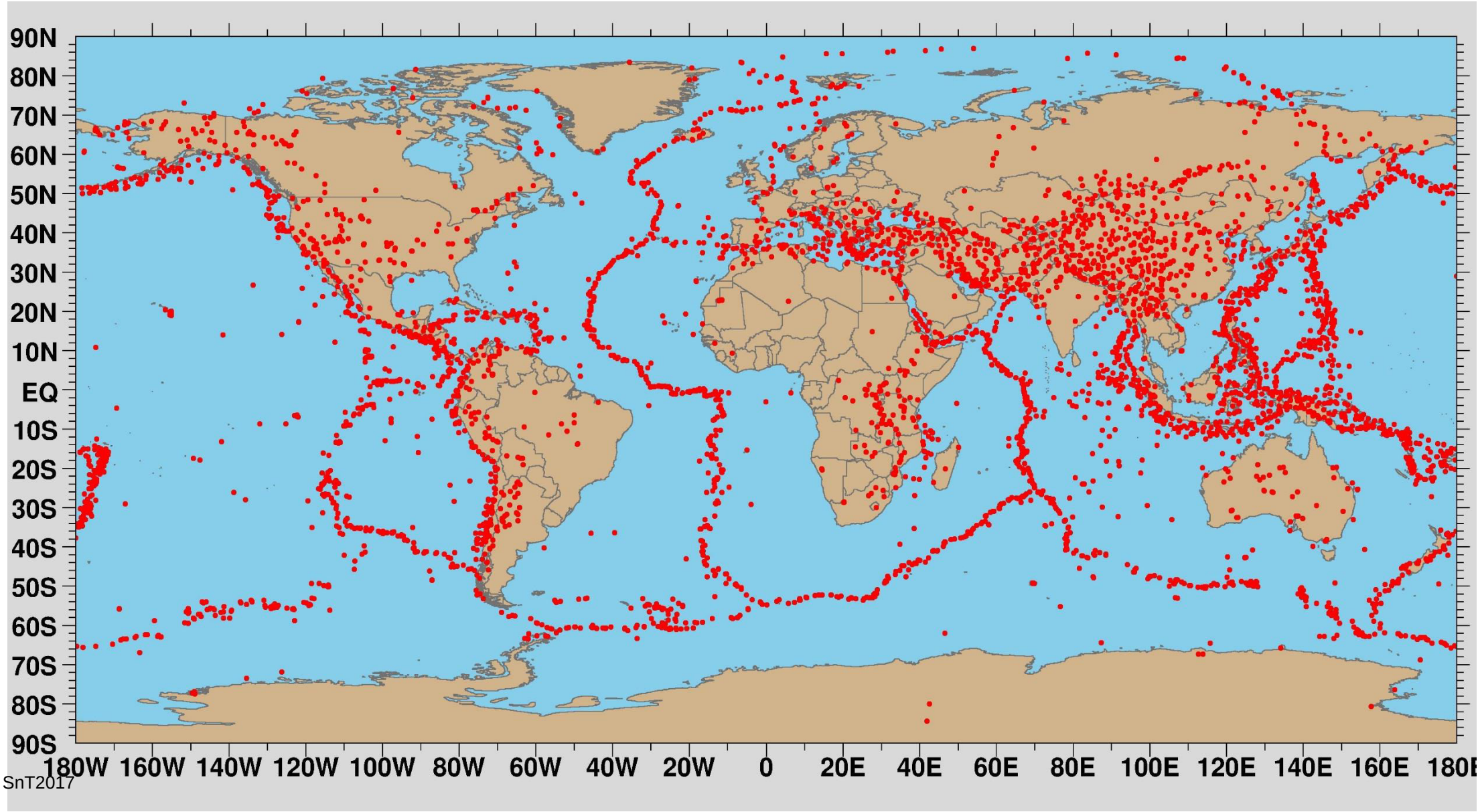
Global grid, ~140 km between nodes



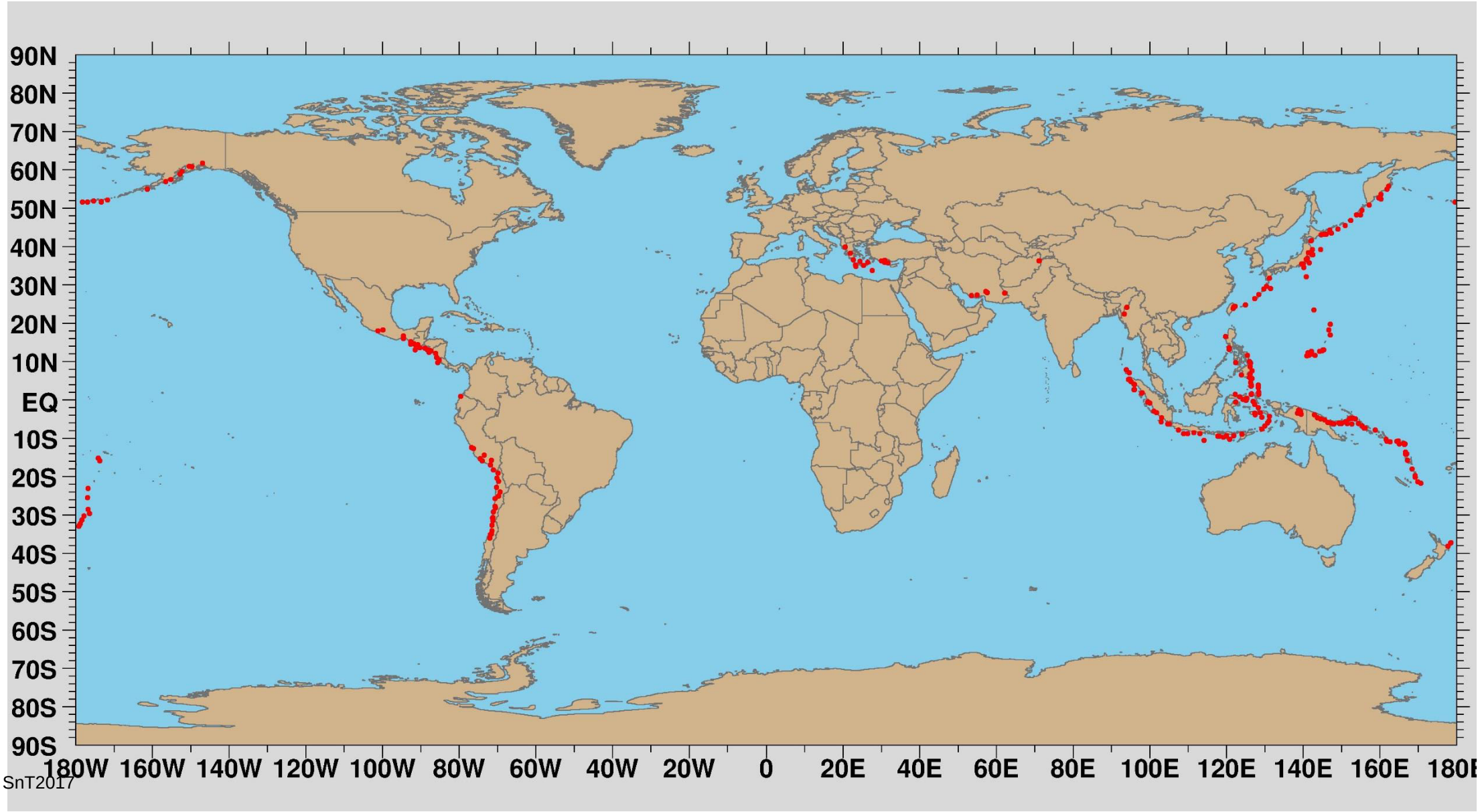
Master events by cross correlation: 0-40 km (1447 events)



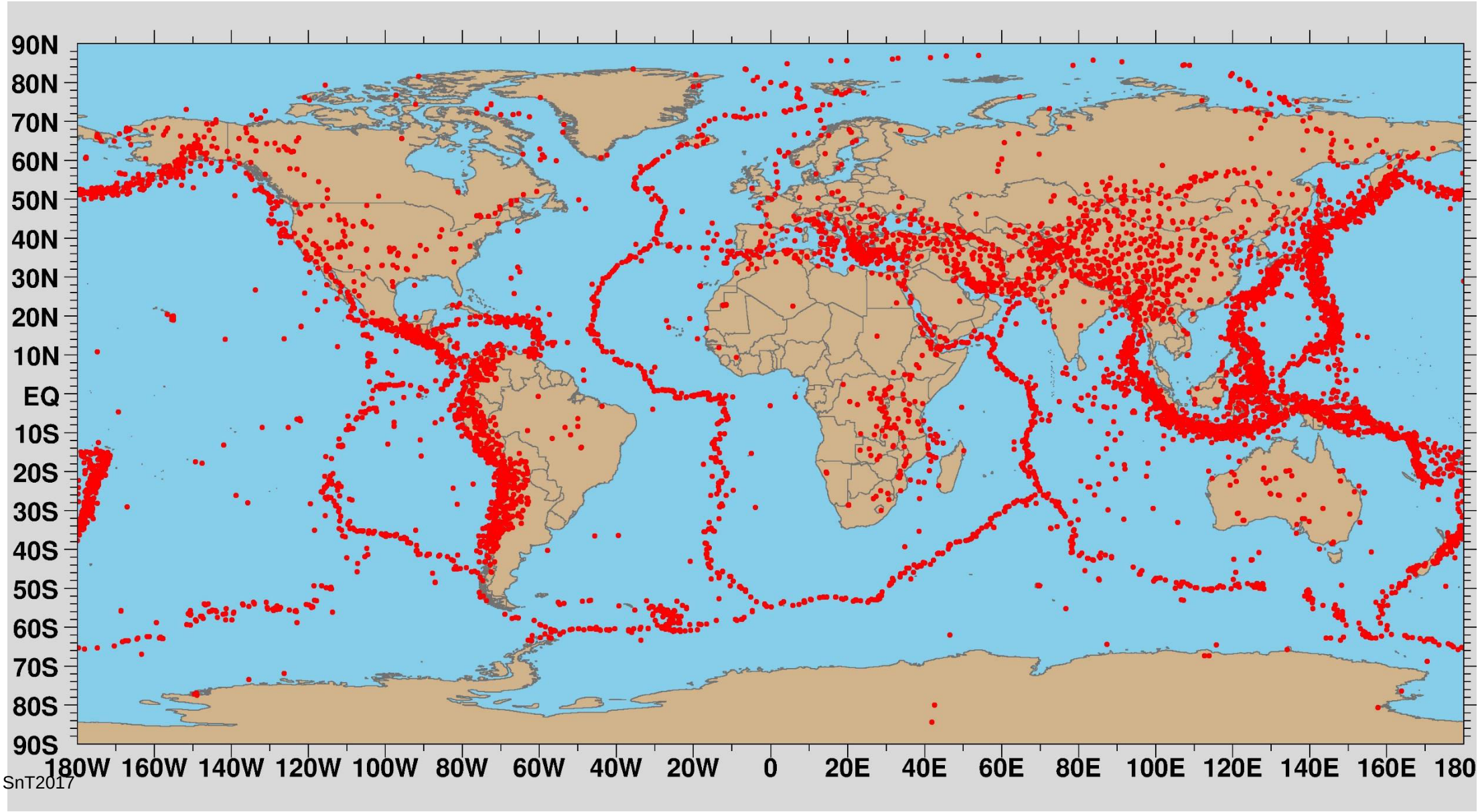
All master events: 0-40 km (~4575)



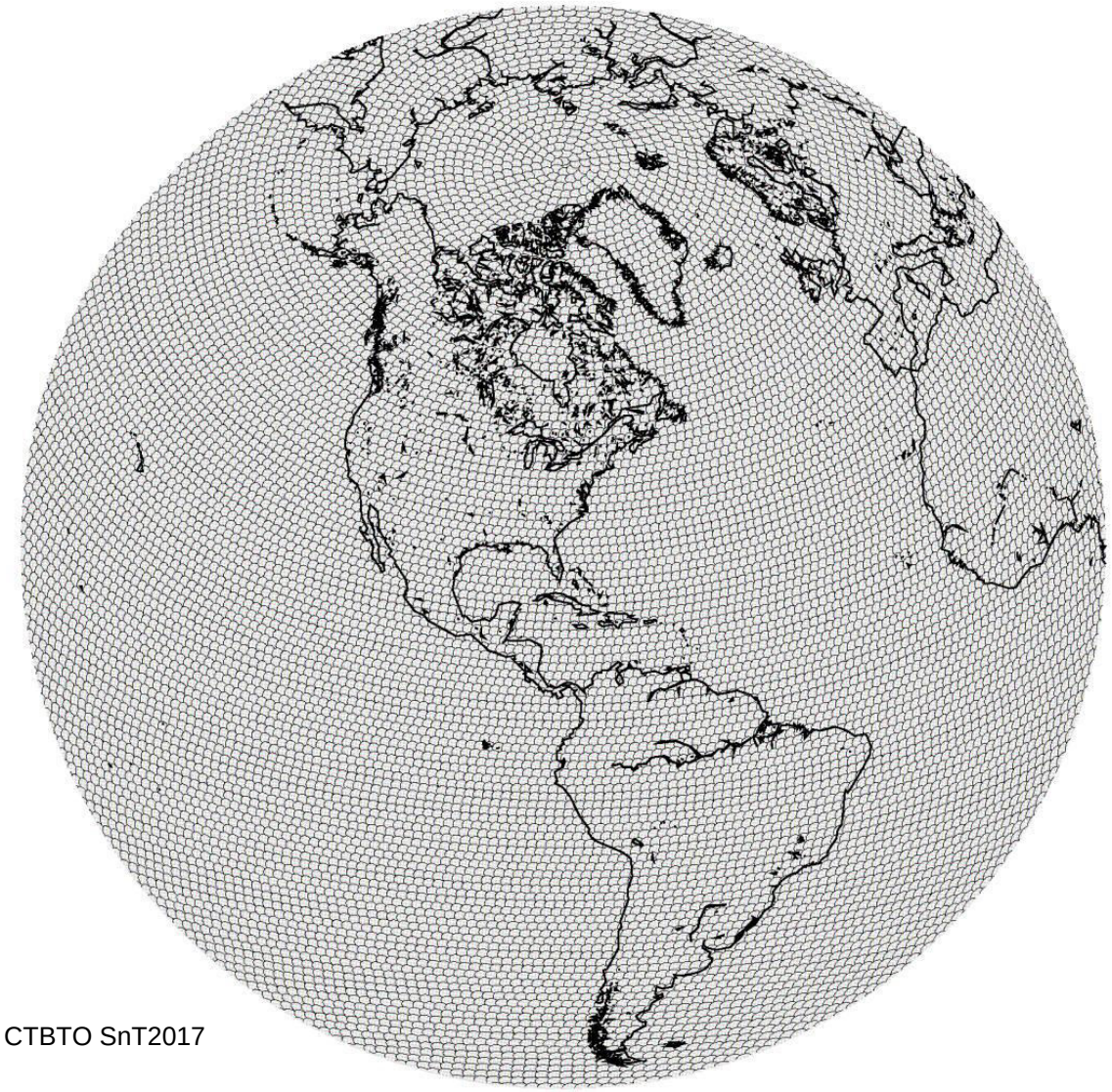
Master events: by cross correlation 40-80 km (292 events)



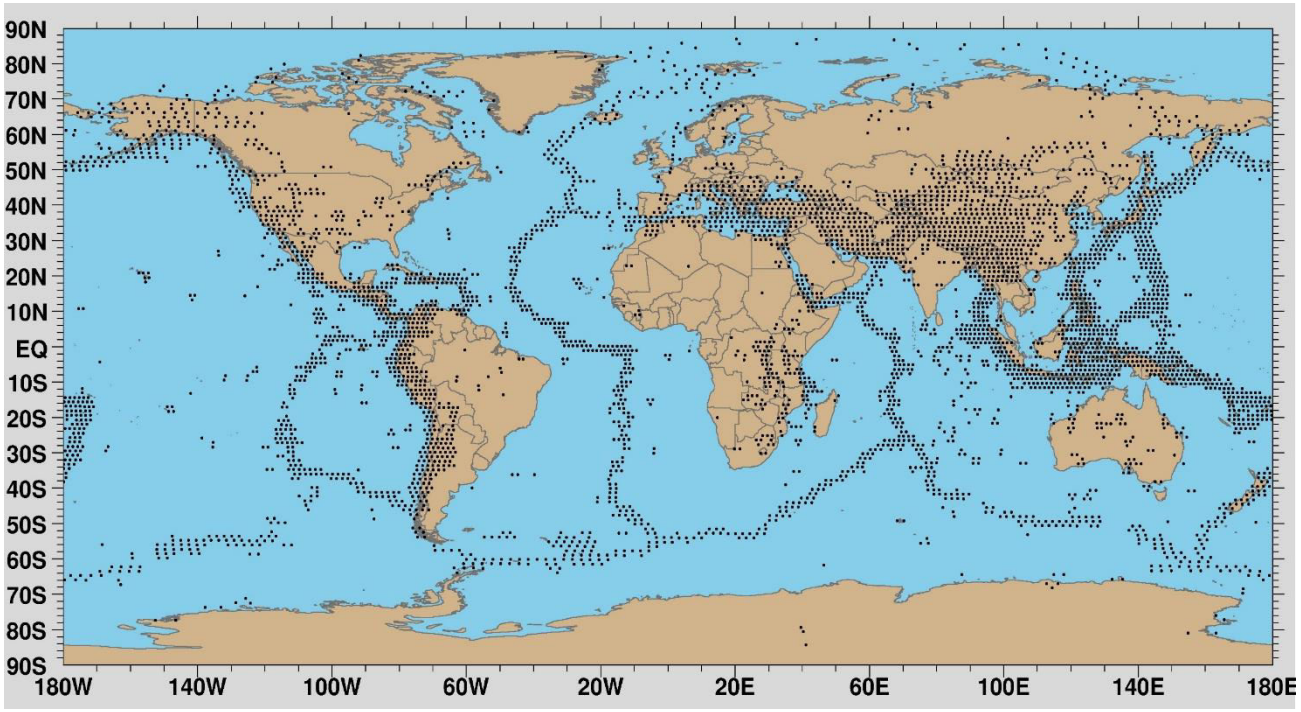
Master events: 0-700 km (~7500 events)



Global grid

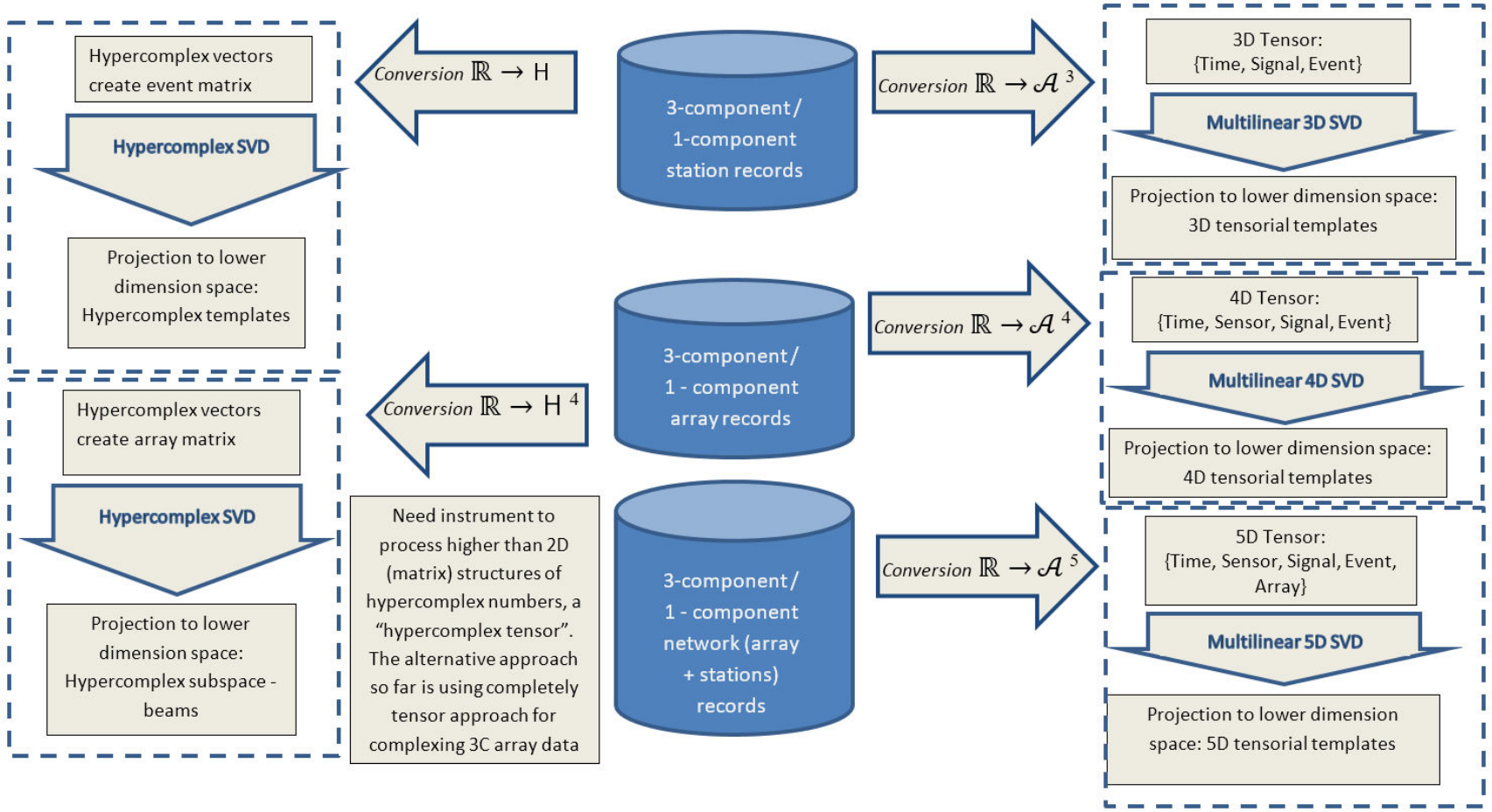


Grid nodes with real master events selected by cross correlation



Multidimensional PCA (Poster T3.5-P20)

Generalized approach to multidimensional master event construction



Multidimensional PCA

High-order dimensionality reduction methods

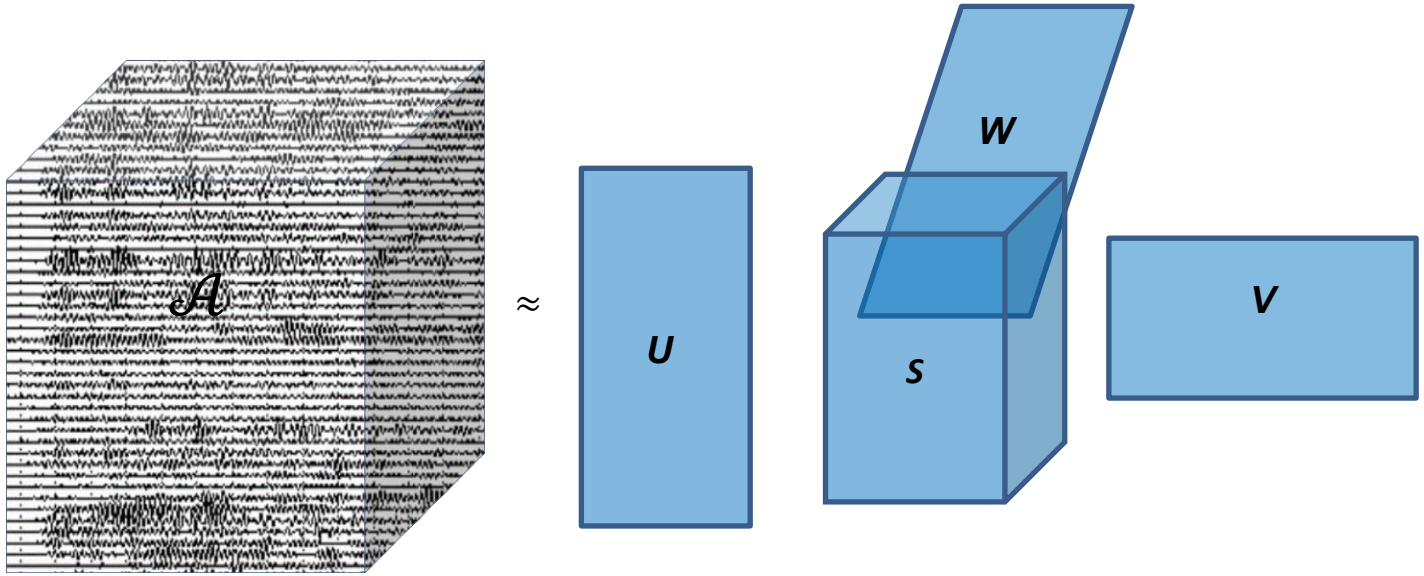
1. Multidimensional discrete cosine transform (DCT)
2. Tensor interpolation
3. Tensor SVD
4. 2D Fourier transform
5. Hyper-complex decomposition of data from 3-C stations

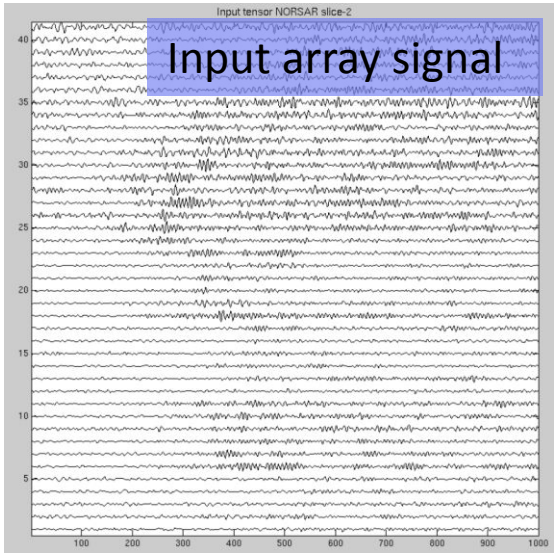
Objects

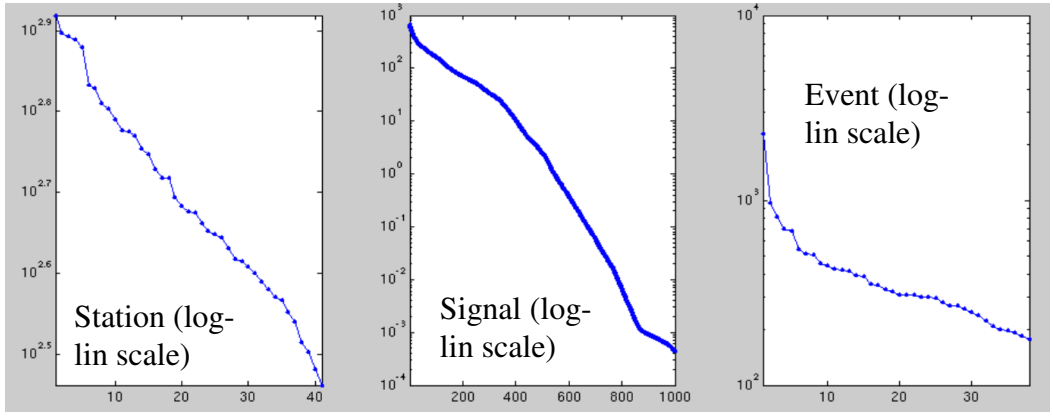
- 3-C station
- Vertical array stations
- 3-C array station
- Inhomogeneous network (global and station templates)

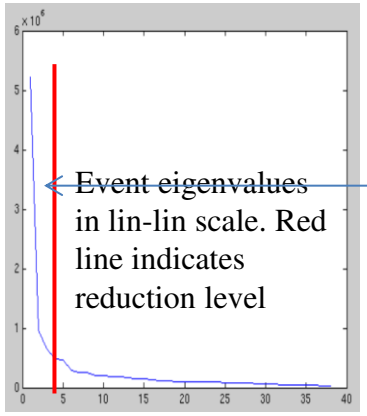
Tensor PCA

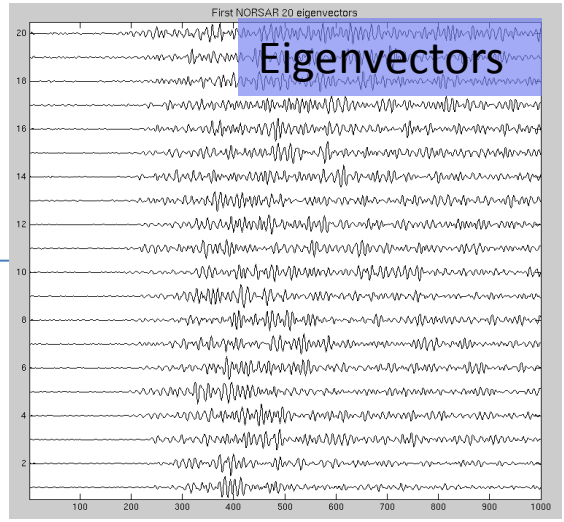
NOA





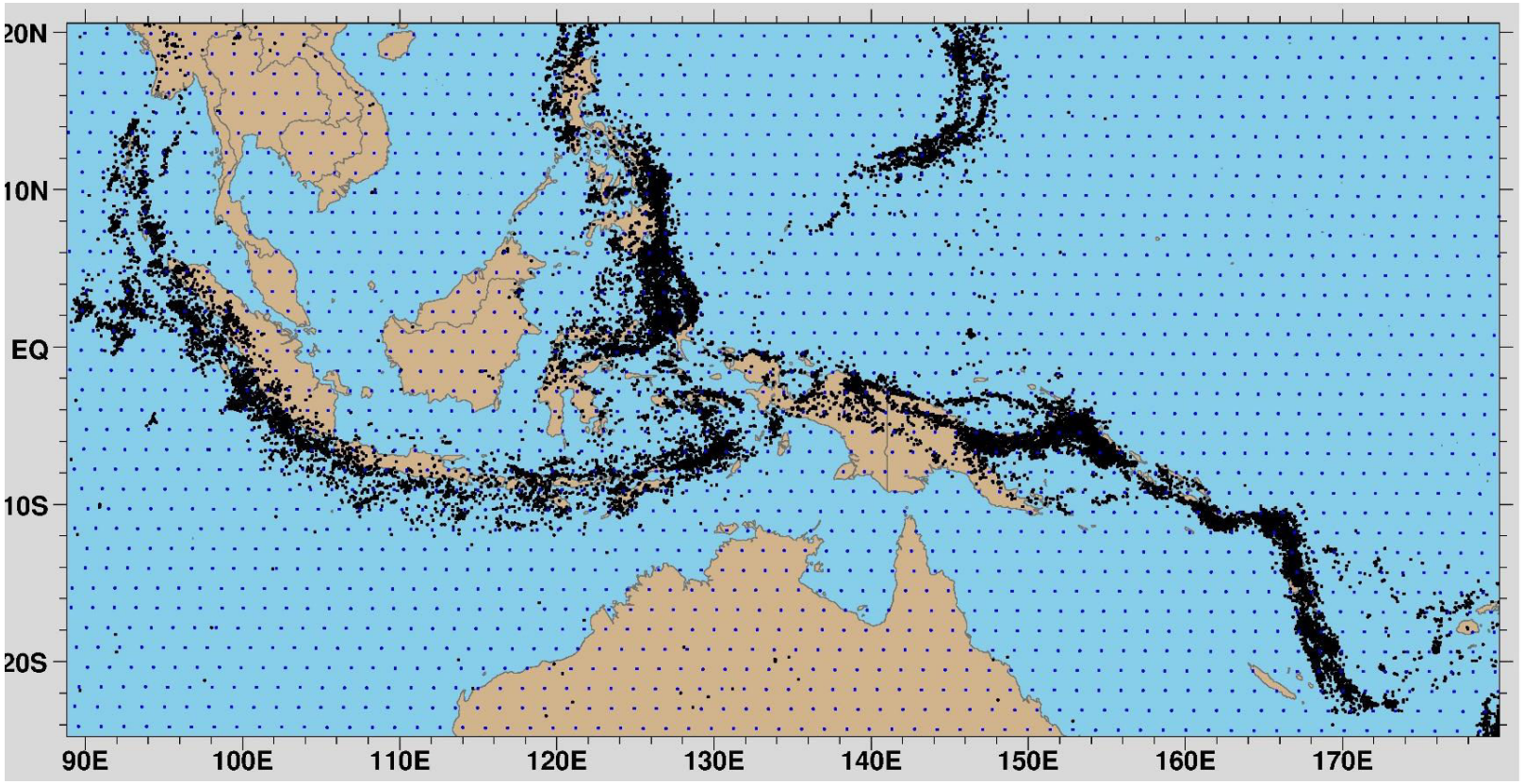




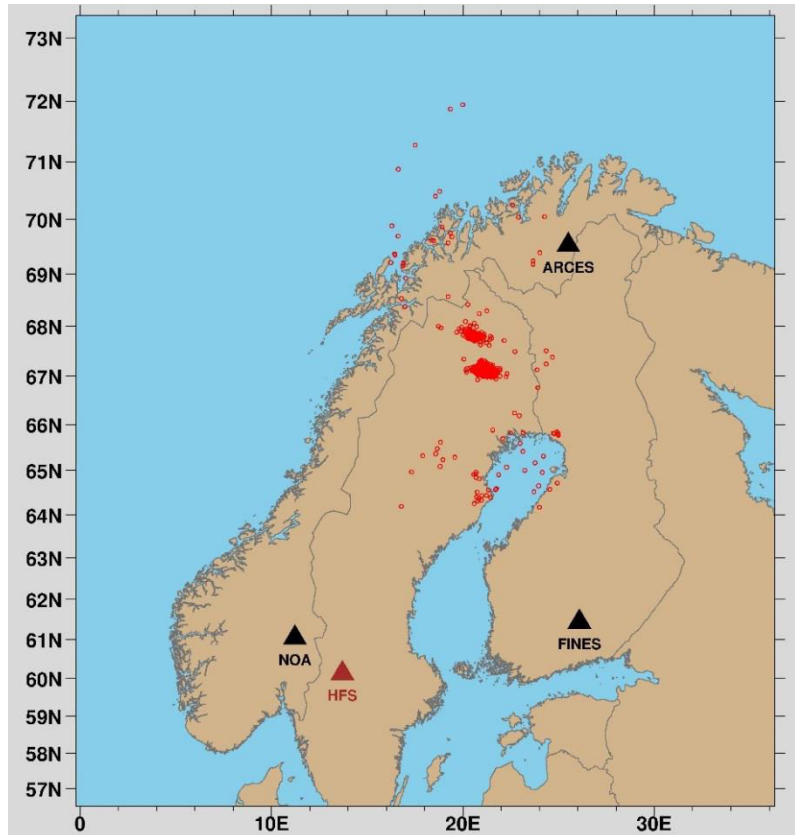


Events for Principal Component Analysis

All quality signals from events within 3 degrees from grid nodes at all IMS stations



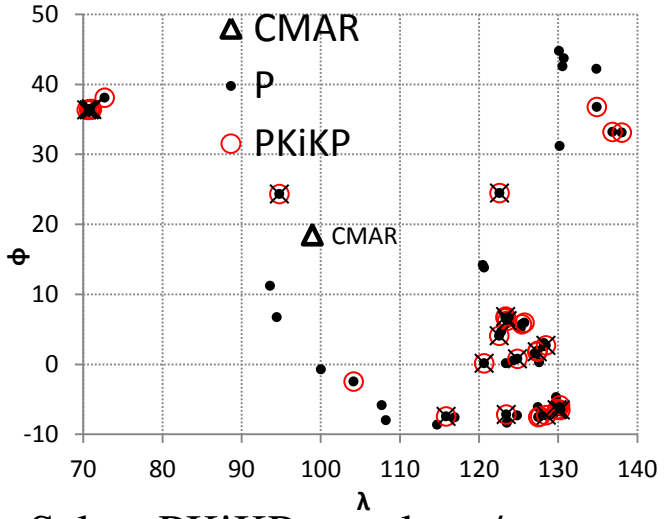
Aitik and Kiruna mines
~150 events



Spot check: new detections

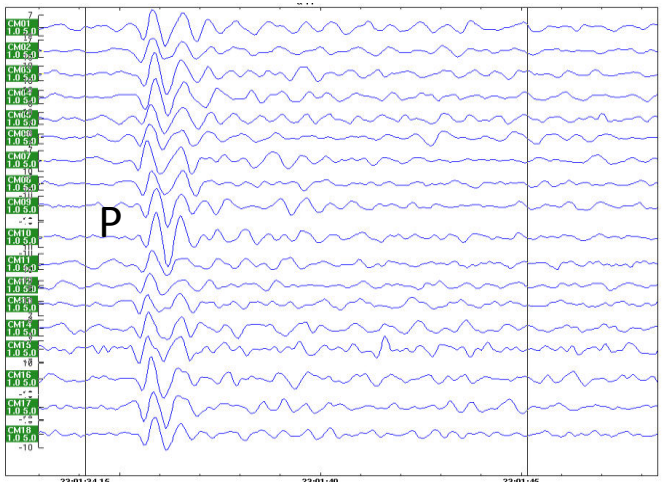
Search for PKiKP at CMAR

Distribution of events

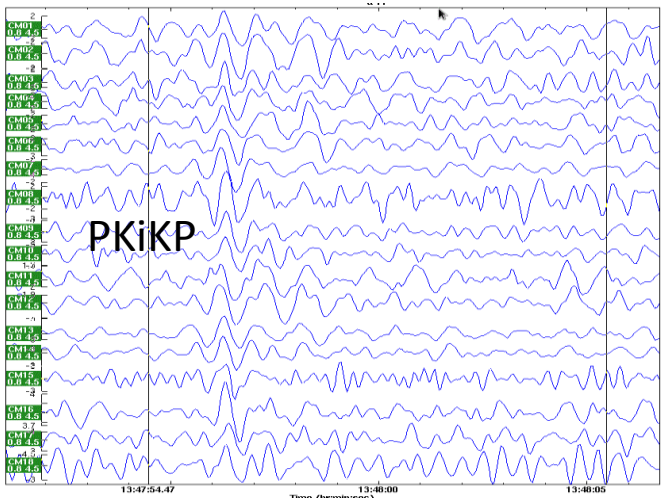


1. Select PKiKP templates/master events
2. Search for correlation with events having PKiKP arrivals at the IDC (34 in total)
3. Search for correlation with events having no PKiKP arrivals at the IDC (77 in total)
4. Determine arrival times and other parameters for the newly find arrivals

orid = 2471404, 36.34N, 70.77E, d=252 km



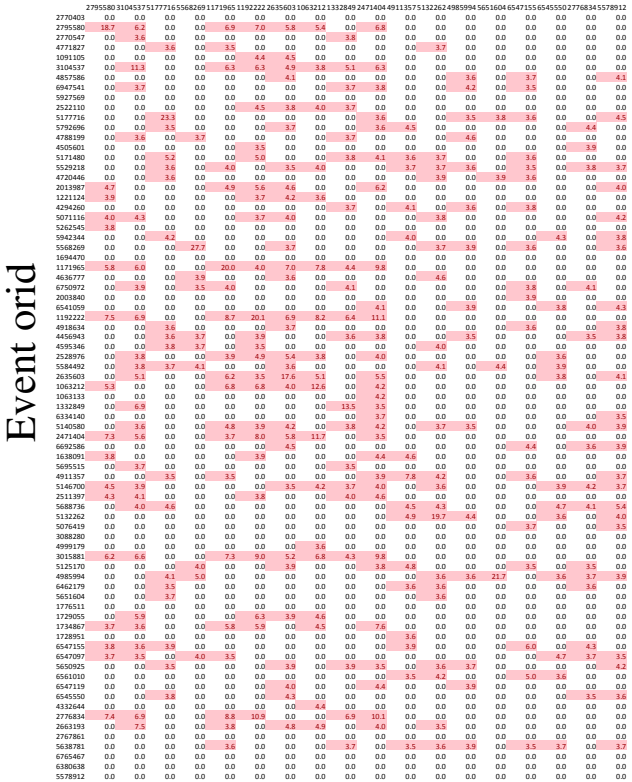
orid = 2795580, 6.51S, 130.3E, d=130 km



Travel time residual for PKiKP, ±10 s

Master orid

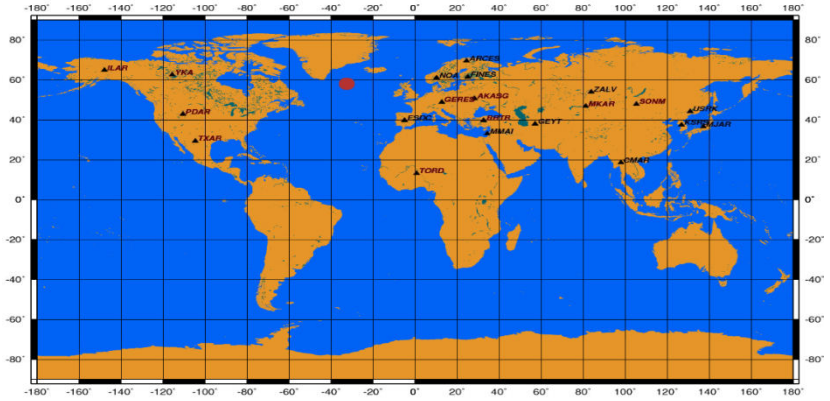
Event orid



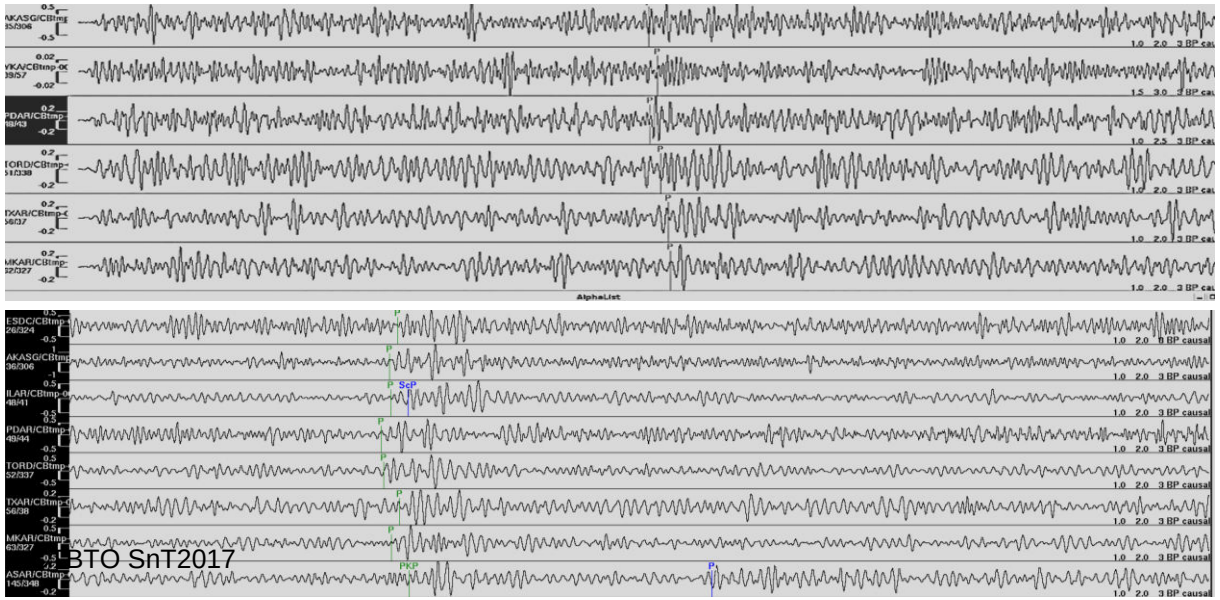
We found **68** new PKiKP arrivals from 77 events with P-arrivals and estimated their parameters

Spot check: new REB events

The main shock



October 5, 2011 57.9526ºN 32.5197ºW, origin time 23:02:10. REB - 36 aftershocks



New REB-compatible events

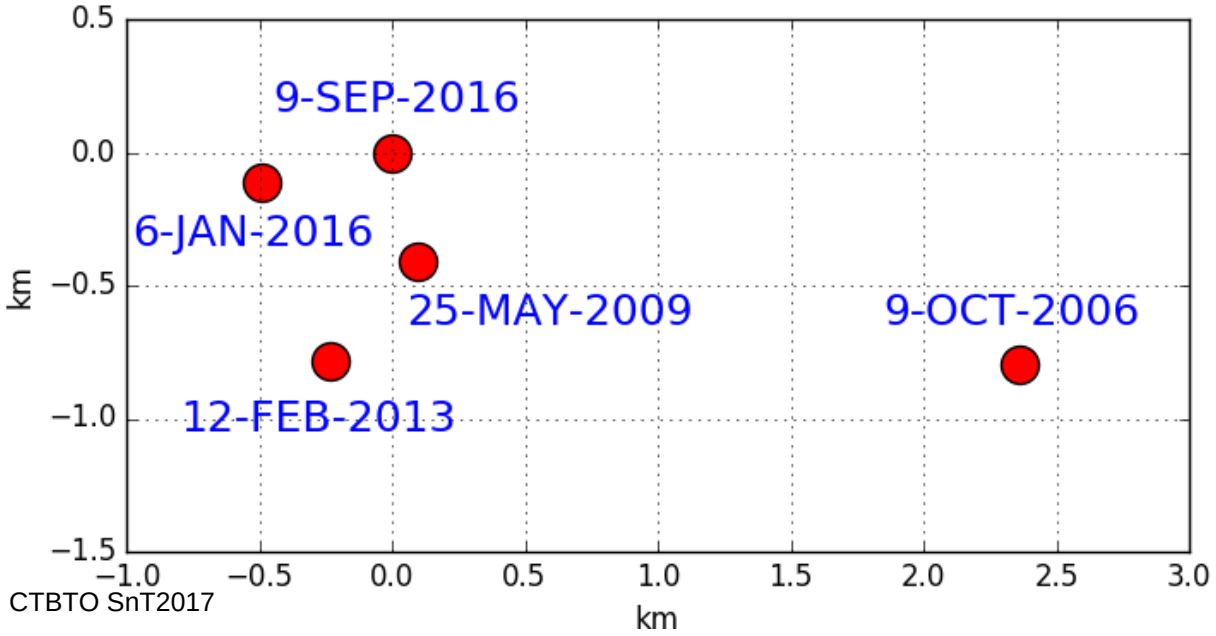
Date	Time	m_b(IDC)	ndef	Dist, km
05/10/2011	23:06:39	3.32	4	49.52
05/10/2011	23:51:58	3.31	5	28.16
05/10/2011	23:54:20	3.80	6	38.17
05/10/2011	23:55:51	3.65	8	13.8
06/10/2011	00:01:38	4.02	10	5.36
06/10/2011	00:02:31	3.59	10	4.79
06/10/2011	00:05:23	3.56	7	35.97
06/10/2011	00:10:45	3.46	3	76.62
06/10/2011	00:39:18	3.42	4	36.28
06/10/2011	00:45:54	3.52	8	9.17
06/10/2011	01:07:19	3.46	8	39.36
06/10/2011	02:31:30	3.37	5	31.8
06/10/2011	02:34:16	3.35	6	61.11
06/10/2011	07:36:33	3.32	5	26.43
06/10/2011	07:47:04	3.59	6	56.75
06/10/2011	07:48:25	3.54	9	24.72
06/10/2011	10:37:51	3.61	5	27.02
06/10/2011	13:17:19	3.54	4	11.75
06/10/2011	14:12:58	3.38	6	8.48
06/10/2011	14:17:29	3.51	8	15.83
06/10/2011	19:43:05	3.40	5	30.34
06/10/2011	19:47:26	3.61	5	15.18
06/10/2011	19:57:48	3.56	6	19.81
06/10/2011	21:12:34	3.51	8	32.3
06/10/2011	21:15:49	3.46	5	18.9
06/10/2011	23:49:25	3.62	9	25.47

26 new events were added to 38 REB events including the main shock. The Reviewed Event Bulletin has been extended by 67%:

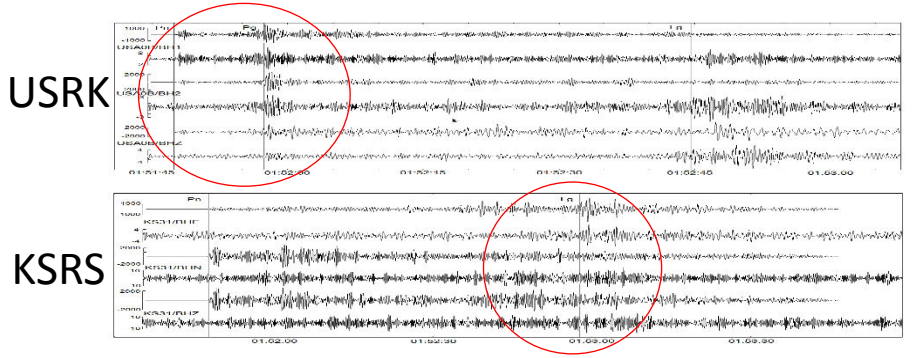
Spot check: monitoring

DPRK explosions as master events: relative location

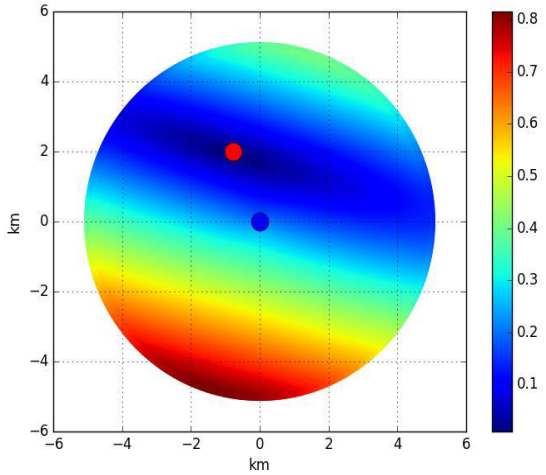
Event	date	Origin time	REB location	IDC m_b	RM
DPRK1	09.10.2006	01:35:27.57	41.312^{0}N, 129.019^{0}E	4.08	3.93
DPRK2	25.05.2009	00:54:42.80	41.311^{0}N, 129.046^{0}E	4.51	4.54
DPRK3	12.02.2013	02:57:50.80	41.301^{0}N, 129.065^{0}E	4.91	4.96
DPRK4	06.01.2016	01:30:00.49	41.304^{0}N, 129.048^{0}E	4.82	4.85
DPRK5	09.09.2016	00:30:00.87	41.299^{0}N, 129.049^{0}E	5.09 (ref)	

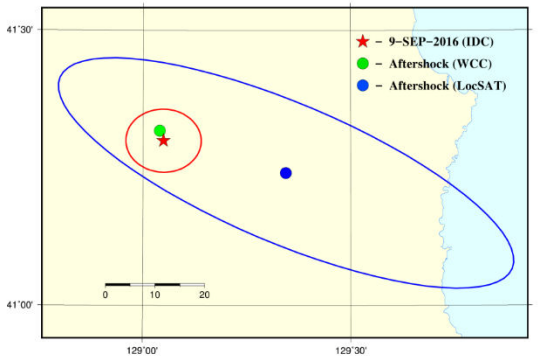


Aftershock: detection and phase association



Sta	Dist, km	EvStaAz, deg	Phase	Arrival time	t_{res}, s	CC	dRM	SNR_{CC}
USRK	410	35.8	P_n	01:51:46.46	0. 1	0.30	-2.61	3.9
KSRS	440	193.6	P_n	01:51:52.16	-0.1	0.21	-2.78	4.3





Low-magnitude events must be **very close** to master events

Discussion

1. Prototype spot check tool based on cross correlation
2. Set of best real master templates: global cover
3. PCA templates: seismic areas
4. Synthetic templates: global cover
5. Synthetic PCA: global cover
6. Tested on REB arrivals
7. Tested on REB events
8. Tested on specific sites – mines, DPRK test site
9. Tested on time intervals from second to months

Future plans

1. Optimization of the PCA based waveform templates
2. Development of analyst friendly tool
3. Comprehensive test of the REB quality and completeness
4. Machine learning