

**Abstract**

This presentation gives an overview of the seismic analysis software package SEISAN. Initially SEISAN was developed to analyse seismic records of earthquakes in local networks, but the package has undergone a steady development so that it today can be applied to seismic sources at all distances including possible nuclear explosions. SEISAN is used in more than 30 countries, mainly in small seismology groups and primarily on Windows or Linux platforms. SEISAN is also used at NDCs in many parts of the world. The architecture of SEISAN is based on a database structure where the three main parts are the parametric data, the waveform data and the metadata. The parametric data are based on the well-established Nordic format, the International Seismological Centre reports that app. 25% of the bulletins they received are in the Nordic format. SEISAN reads a number of waveform formats, but miniseed is preferred. Waveform data can be stored in SDS, BUD or a SEISAN structured file systems. SEISAN reads instrument metadata in an internal format, but also in SEED and GSE format. Data examples showing how SEISAN can aid smaller NDCs are given based on data from the IMS and on data from local a seismic network.

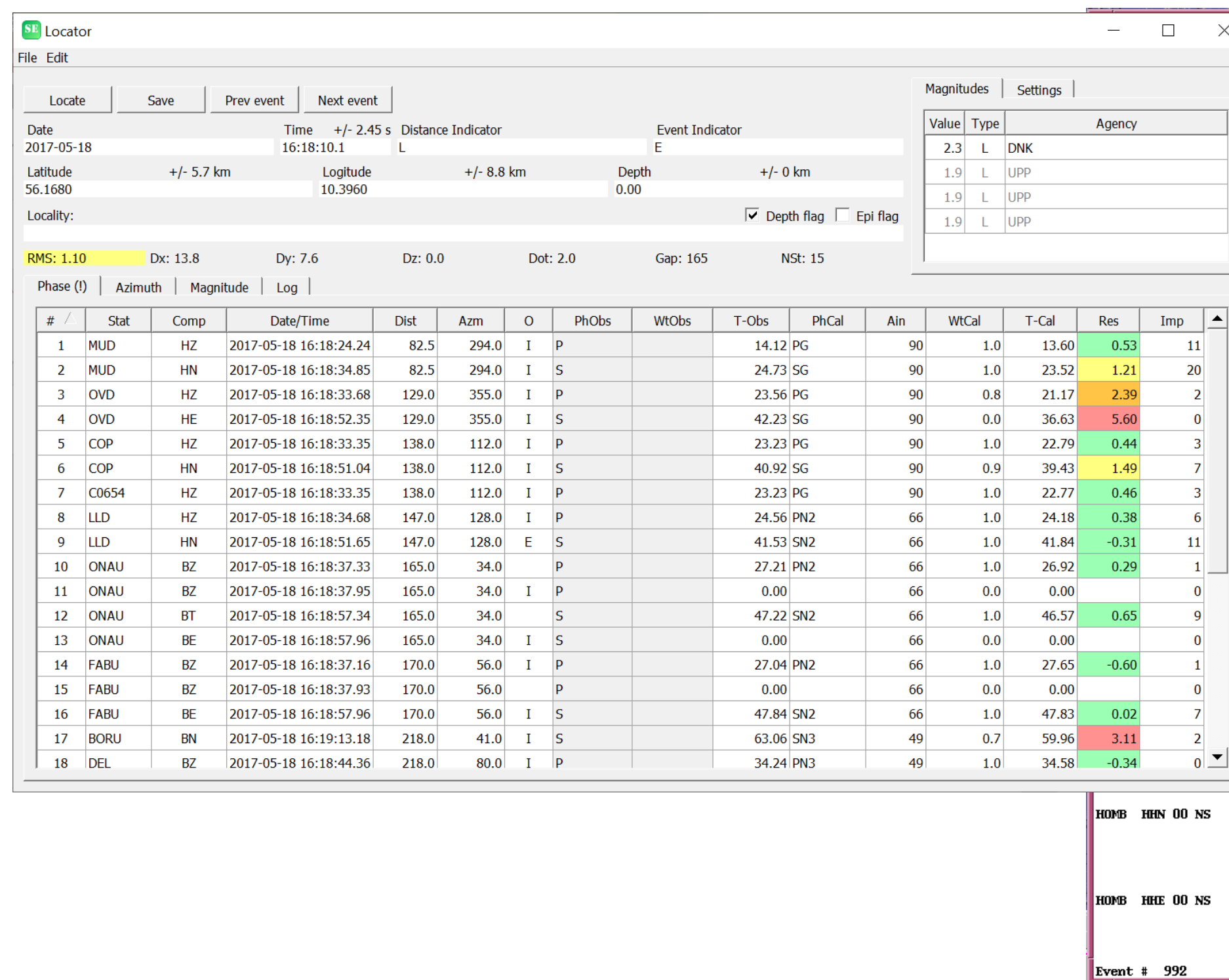
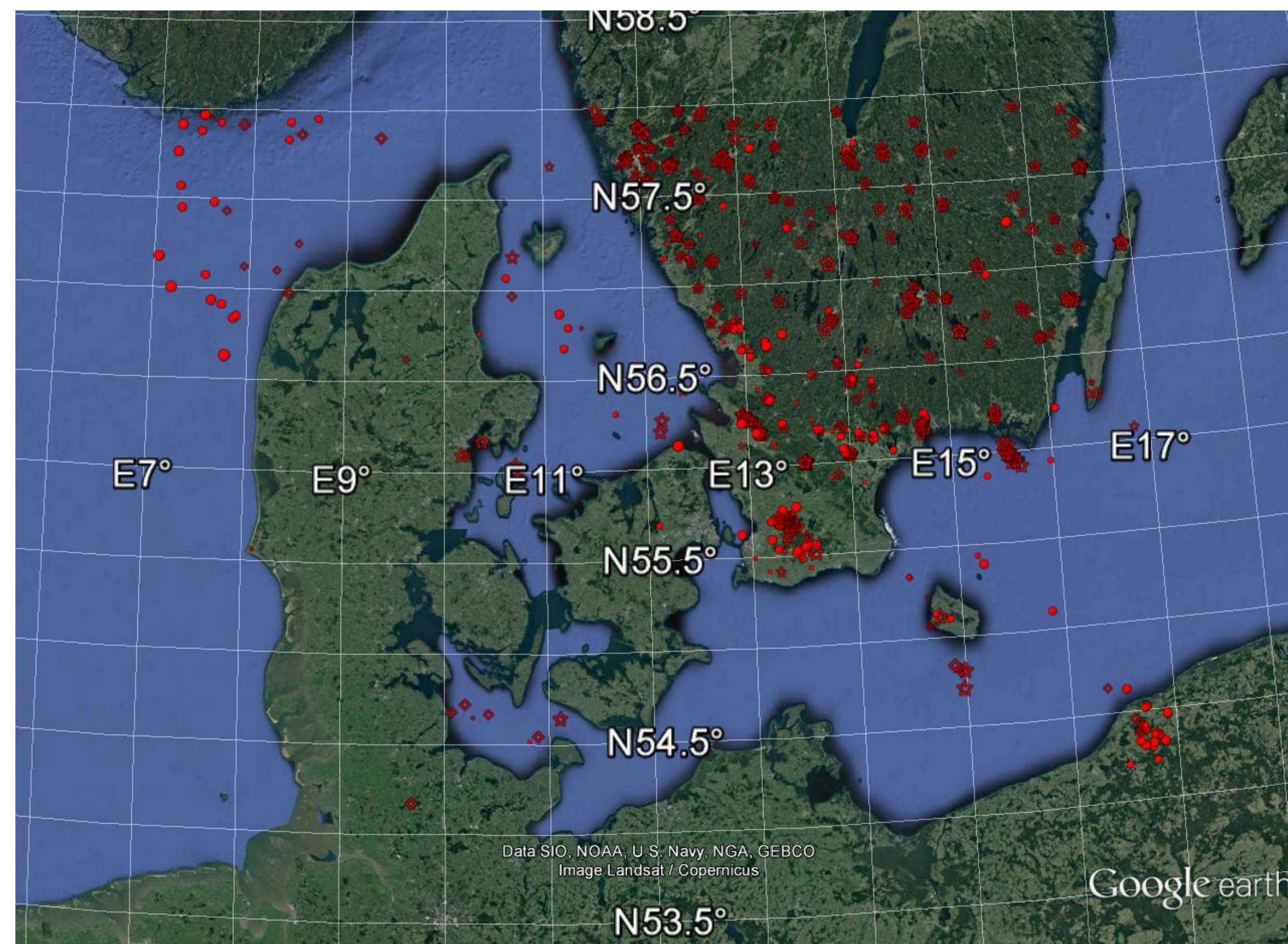
Seisan Explorer 2.7.0 beta - Database: PVOSS (C:\Seismo\REA\PVOSS) 895 events.

Row	Ac	Date and Time	Lat	Lon	Dep	Mod	Aq	RMS	Gap	ELat	ELon	EDEP	DI	EI	AIIn	NSI	M	MW	ML	MN
1	SPL	2017-01-02 12:59:48.70	56.2040	13.3570	0.0F	DNK	0.10	92.0	1.8	1.0	0.0	L	E			8	1.0	1.0		
2	SPL	2017-01-02 13:59:58.60	57.6830	12.9250	0.0F	DNK	0.30	58	1.6	3.1	0.0	L	E			11	0.9	0.9		
3	SPL	2017-01-03 10:00:27.00	57.7260	11.8570	0.0F	DNK	0.20	164	1.0	2.8	0.0	L	E			10	0.9	0.9		
4	SPL	2017-01-03 10:05:06.20	56.3380	13.4990	0.0	DNK	1.30	103	11.0	22.8	44.7	R	E			6				
5	SPL	2017-01-03 11:27:05.50	57.6750	12.1370	0.0F	DNK	0.10	120	0.7	1.6	0.0	L	E			10	1.3	1.3		
6	SPL	2017-01-03 14:00:03.50	57.8940	11.9990	0.0F	DNK	0.10	120	0.7	1.6	0.0	L	E			8	2.5	2.5		
7	SPL	2017-01-03 14:03:56.70	57.6860	12.3470	0.0F	DNK	0.20	94	0.9	1.9	0.0	L	E			12	1.2	1.2		
8	SPL	2017-01-04 12:26:21.00	56.0100	13.5640	0.0F	DNK	0.10	114	0.7	1.6	0.0	L	E			7	1.3	1.3		
9	SPL	2017-01-04 13:37:22.80	57.6750	12.3020	0.0F	DNK	0.20	118	1.0	1.6	0.0	L	E			6	0.8	0.8		
10	SPL	2017-01-04 13:41:28.80	57.6800	12.3400	0.0F	DNK	0.20	94	0.8	1.5	0.0	L	E			13	1.3	1.3		
11	SPL	2017-01-05 12:10:17.30	57.3820	12.2980	0.0F	DNK	0.20	112	1.1	1.6	0.0	L	E			8	1.0	1.0		
12	SPL	2017-01-05 12:34:28.00	57.1370	12.5020	0.0F	DNK	0.20	145	1.0	2.4	0.0	L	E			11	1.2	1.2		
13	SPL	2017-01-07 04:35:17.80	57.8360	8.3670	15.0	DNK	1.00	218	43.9	44.6	94.8	R				3	1.4	1.4		
14	SPL	2017-01-09 05:17:07.50	57.3460	7.0580	15.0	DNK	1.10	325	999.9	184.7	999.9	R				2				
15	SPL	2017-01-09 10:58:06.50	55.7110	13.3560	0.0F	DNK	0.60	186	2.6	8.9	0.0	L	E			6	1.2	1.2		
16	SPL	2017-01-09 10:58:41.20	55.6860	13.3390	0.0F	DNK	0.20	203	1.3	2.8	0.0	L	E			5	1.4	1.4		
17	SPL	2017-01-09 10:59:09.90	55.7060	13.3530	0.0F	DNK	0.20	188	1.4	3.1	0.0	L	P			5	1.3	1.3		
18	SPL	2017-01-09 12:13:17.60	57.7330	11.8680	0.0F	DNK	0.10	161	0.7	2.4	0.0	L	E			10	1.0	1.0		
19	SPL	2017-01-09 13:36:18.80	56.1920	14.7440	0.0F	DNK	0.50	96	1.9	3.2	0.0	L	E			10	1.3	1.3		
20	SPL	2017-01-09 14:08:31.20	56.6070	15.9660	0.0F	DNK	0.70	156	2.5	6.4	0.0	L	E			14	1.2	1.2		
21	SPL	2017-01-10 10:10:22.30	55.6730	13.3120	2.7	DNK	0.70	260	7.6	31.6	19.6	R				4	0.9	0.9		
22	SPL	2017-01-10 12:36:32.40	57.6820	12.3270	0.0F	DNK	0.10	96	0.8	1.4	0.0	L	E			10	1.6	1.6		
23	SPL	2017-01-10 13:31:53.00	55.5140	13.6170	0.0F	DNK	0.10	264	5.6	4.2	0.0	L	E			5	2.5	2.5		
24	SPL	2017-01-11 12:50:44.90	57.4870	14.7690	0.0F	DNK	0.20	83	1.3	1.8	0.0	L	E			12	1.3	1.3		
25	SPL	2017-01-11 15:00:32.10	57.1060	16.9030	0.0F	DNK	0.10	200	1.3	2.3	0.0	L	E			5	2.6	2.6		
26	SPL	2017-01-12 12:11:22.80	57.5400	16.5510	0.0F	DNK	0.10	77	0.6	1.4	0.0	L	E			10	2.6	2.6		
27	SPL	2017-01-12 14:15:04.90	57.7820	12.0050	0.0F	DNK	0.20	134	1.1	2.7	0.0	L	E			9	1.3	1.3		
28	SPL	2017-01-12 16:03:21.70	57.9140	7.2300	21.0	DNK	0.40	297	10.8	13.2	7.6	R				3	2.4	2.4		
29	SPL	2017-01-13 13:08:35.40	57.6710	14.1640	0.0F	DNK	0.60	38	1.7	3.4	0.0	L	E			19	1.2	1.2		
30	SPL	2017-01-16 12:39:35.90	56.2270	13.0680	5.1	DNK	0.40	157	1.9	6.8	7.0	R				6				
31	SPL	2017-01-16 15:43:20.00	57.1030	16.9060	0.0F	DNK	0.10	201	1.0	1.9	0.0	L	E			5	1.8	1.8		
32	SPL	2017-01-17 09:27:11.20	56.3400	16.4590	0.0F	DNK	0.30	176	1.6	3.2	0.0	L	E			9	1.2	1.2		
33	SPL	2017-01-17 11:04:50.30	55.6720	13.4000	0.0F	DNK	0.50	186	3.5	7.9	0.0	L	E			7	1.8	1.8		
34	SPL	2017-01-17 13:42:56.50	57.7080	11.8550	0.0F	DNK	0.50	166	1.5	4.4	0.0	L	E			12	1.5	1.5		
35	SPL	2017-01-17 13:42:54.90	57.6930	11.8550	0.0F	DNK	0.20	167	1.5	4.6	0.0	L	E			6	1.3	1.3		
36	SPL	2017-01-17 14:15:01.50	57.7810	12.8070	0.0F	DNK	0.20	134	0.9	2.9	0.0	L	E			9	1.3	1.3		
37	SPL	2017-01-17 23:25:06.00	56.6770	11.2000	9.4	DNK	0.50	131	3.0	5.5	8.5	L	Q			9	1.6	1.6		

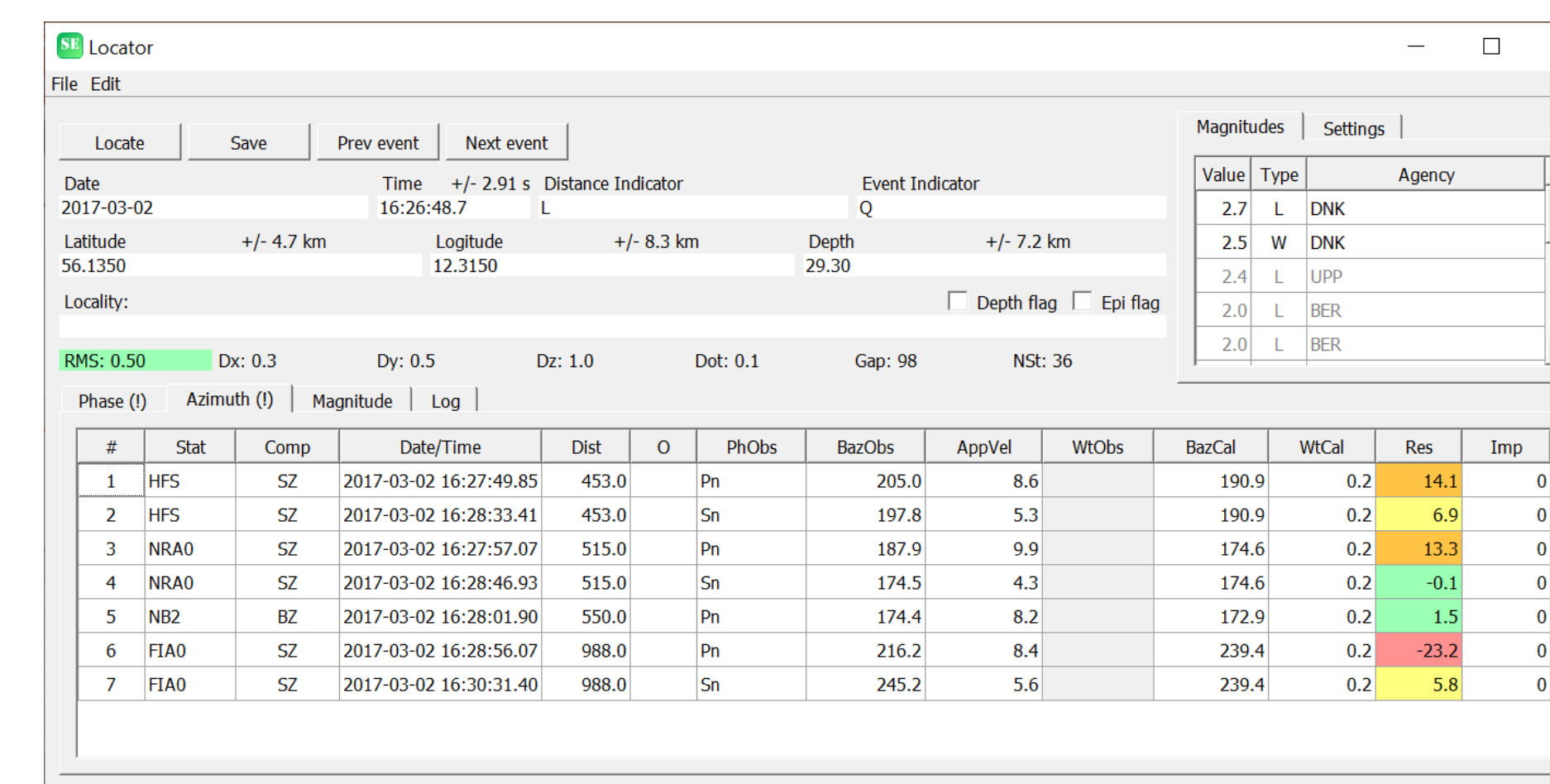
TIME INTERVAL: 2013.05.17 - 2019.06.17 OPERATOR: PV

SEISAN consist of software libraries for reading and writing waveform data and parameters files. The GUI SEISAN Explorer consist of a basic event list viewer with status bars, seen above. SEISAN include a number of exporting options to KML. A KML files is view in Goggle Earth below, showing a subset of events from the GEUS database, using SEISAN search and exporting options. The Map show events from DNK database 2017, selected area 54N-58N 7E- 17E

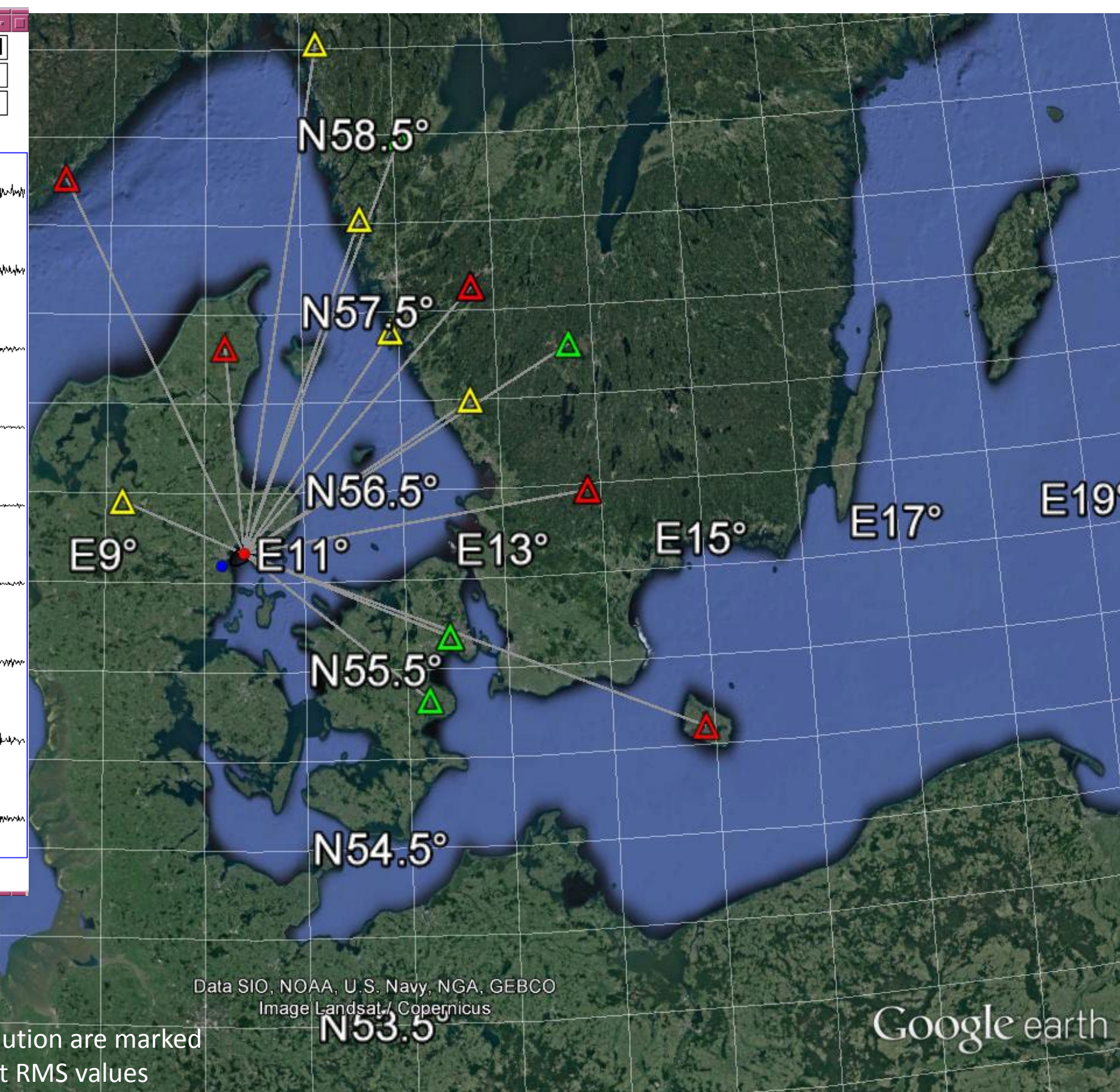
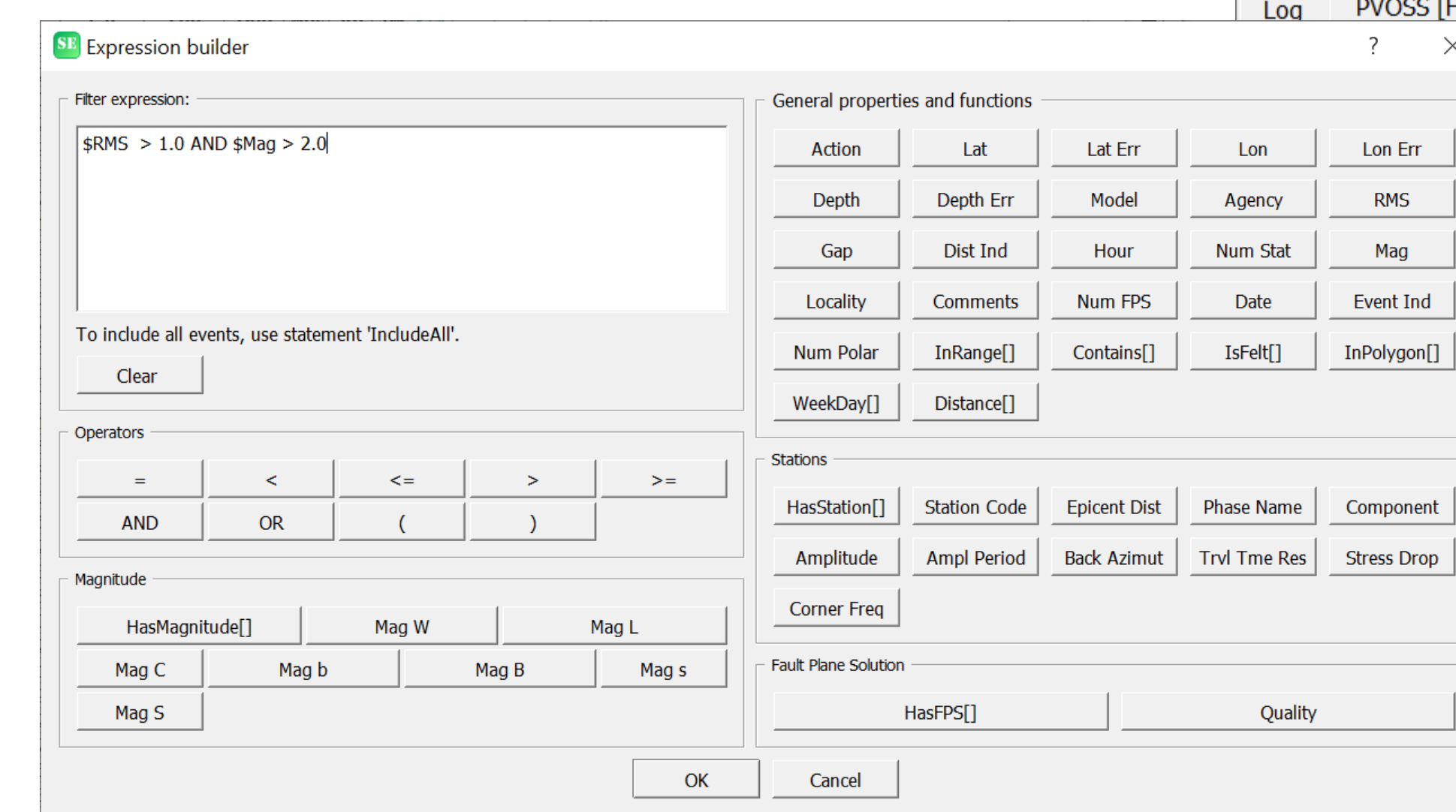
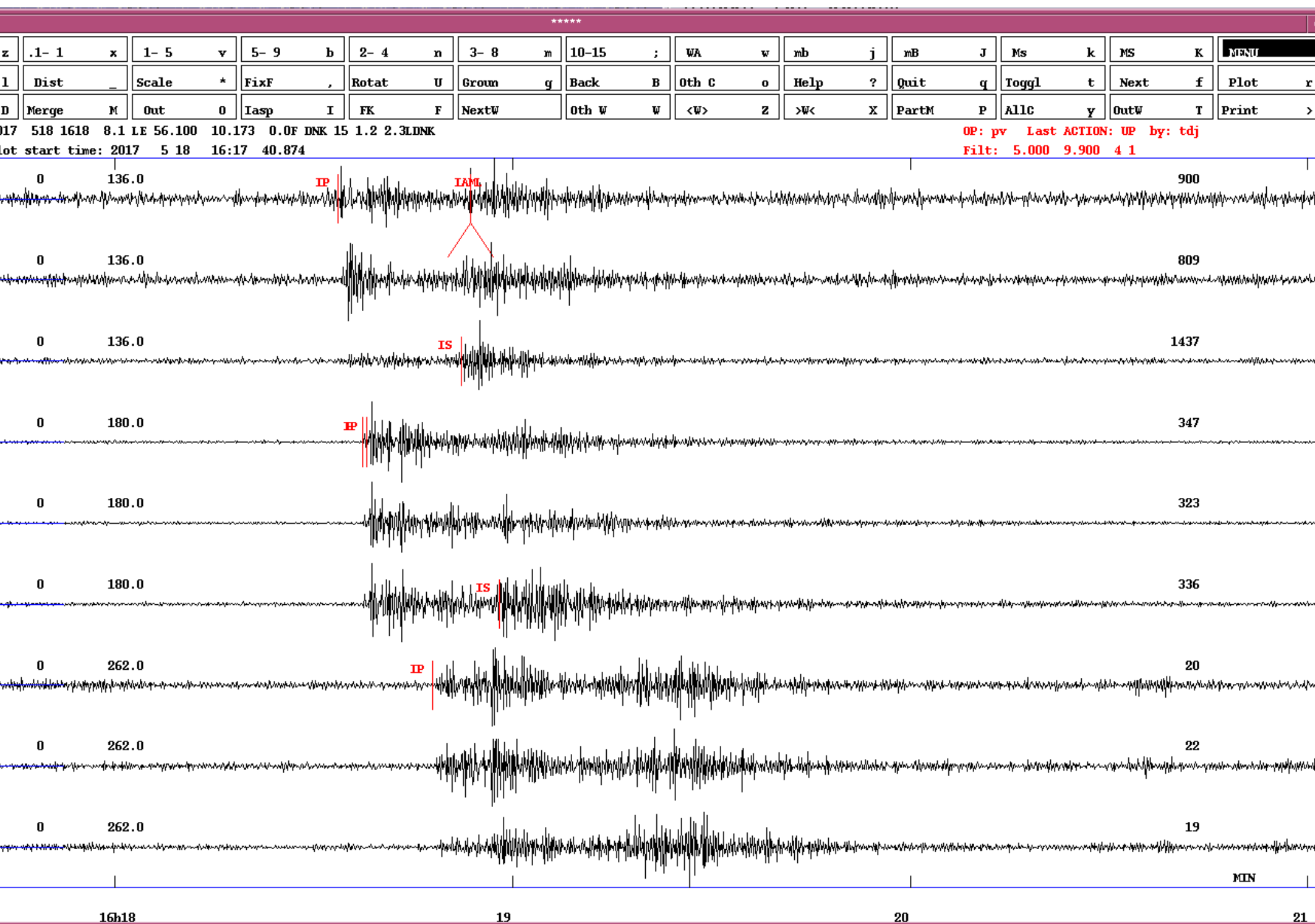
Number of Earthquakes: 209  
Explosions: 653  
Probable Explosions: 40



For analyzing seismic events in SEISAN, users will normally use the three windows above. The Locator, MULPLT and Google Earth. The Locator is a tool to view the parametric data, is interact with the plotting tool for the waveform data MULPLT. Important parameters as RMS and residuals are highlighted. MULPLT is the tool for plotting and processing waveform data. The user will do phase and amplitude picking in MULPLT, but many additional tools for e.g. focal mechanism and spectral amplitudes are also available in MULPLT. As an event is located and re-located SEISAN will send KML files to Google Earth, to be automatically plotted, as seen above.



Measures and residuals of back-azimuthal values in the SEISAN Locator from IMS seismic arrays are illustrated above. Data used are AS101: HFS, PS27: NRAO and N82 and reference point for PS17: FIAO.



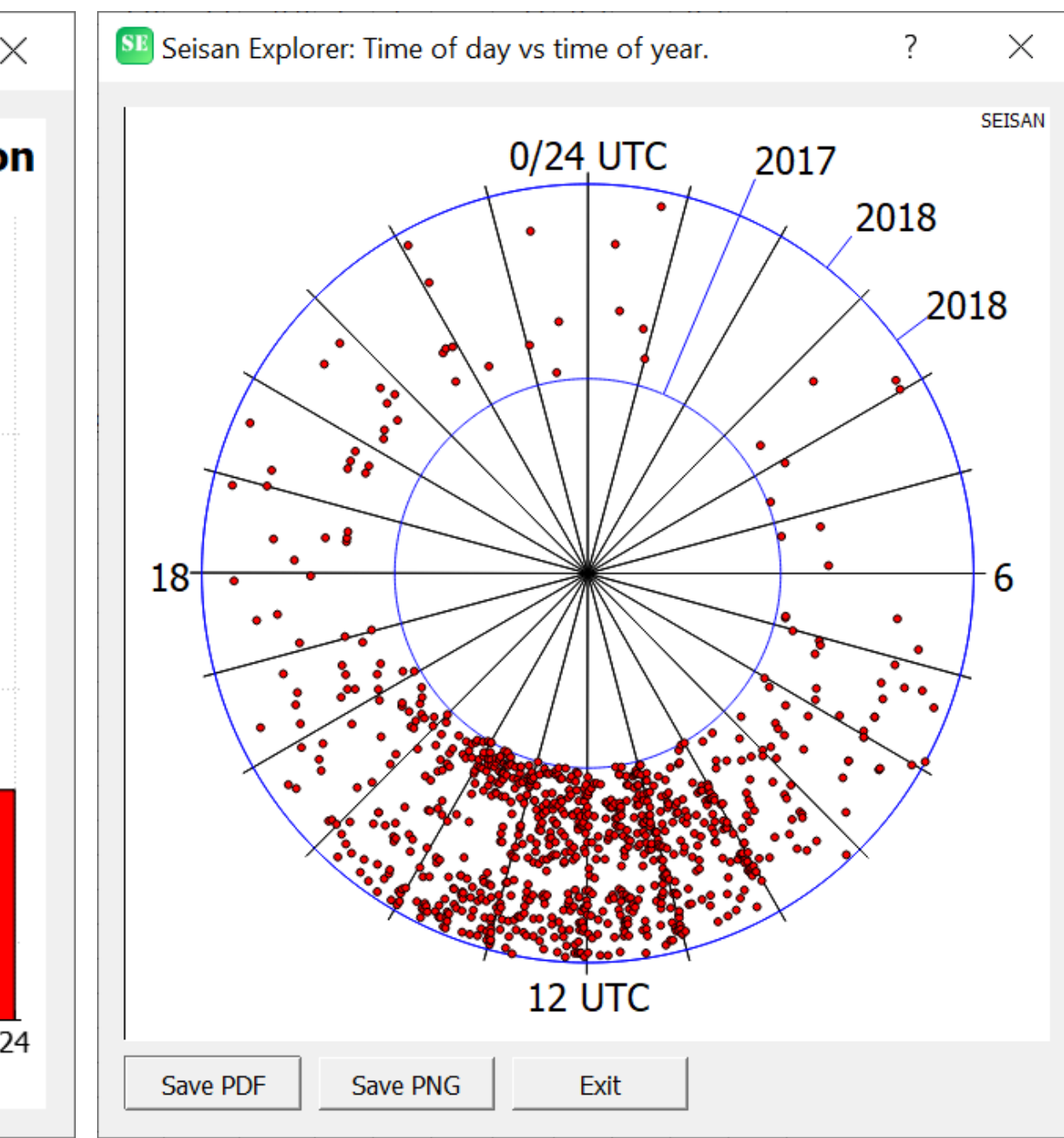
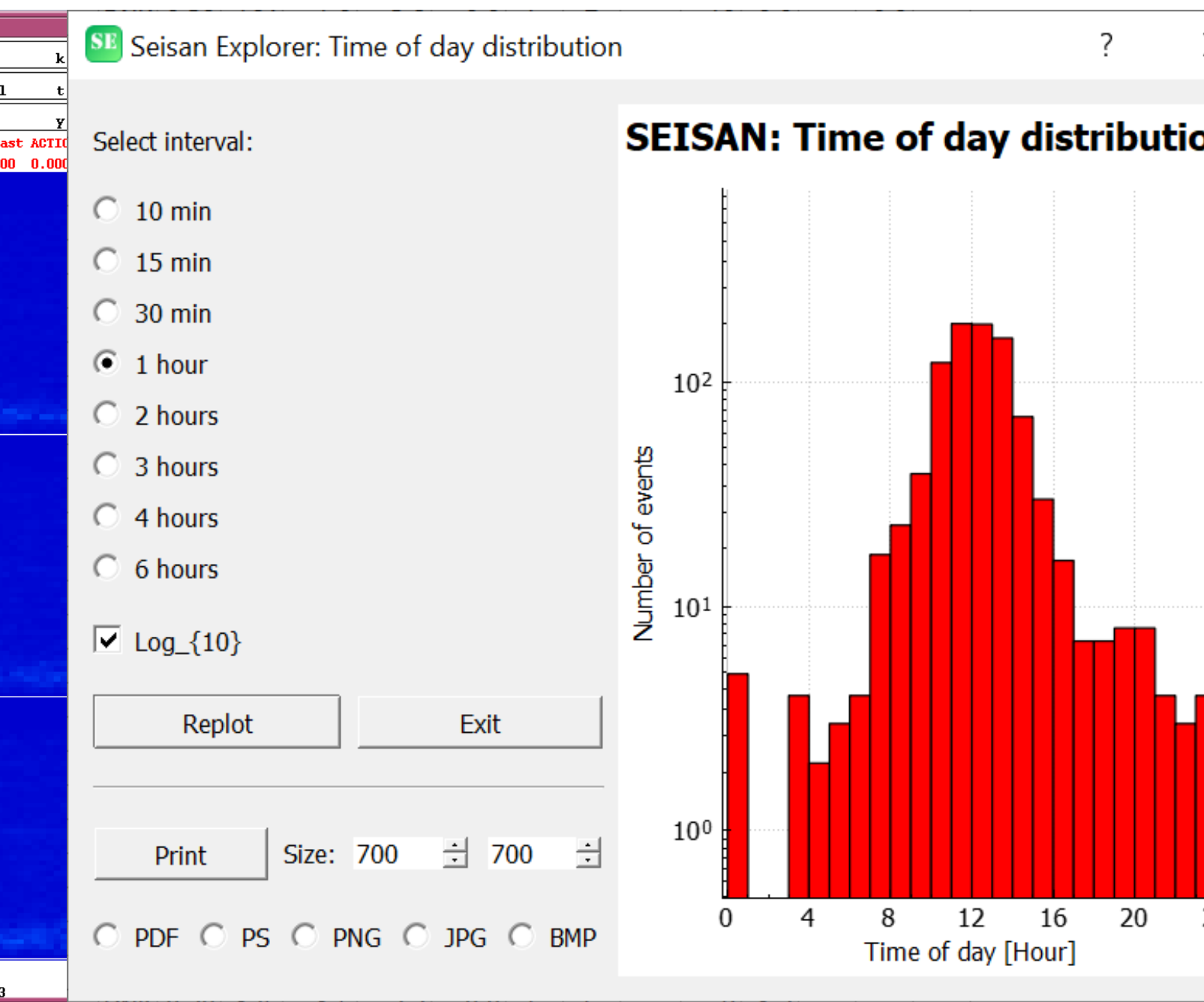
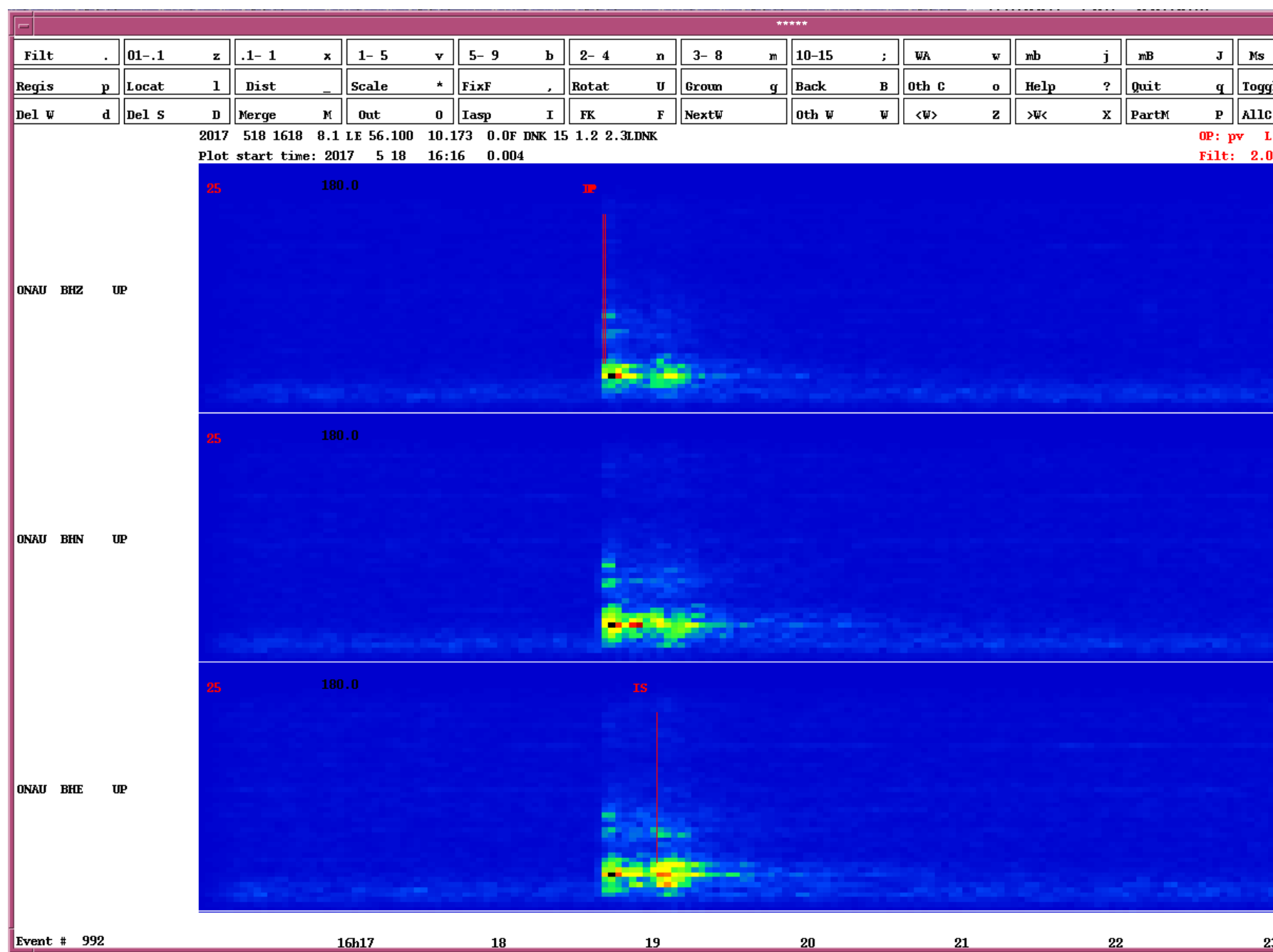
The stations used in the solution are marked with triangles, colors reflect RMS values

Seisan Explorer 2.7.0 beta - Database: PVOSS (C:\Seismo\REA\PVOSS) 9 events.

Row	Ac	Date and Time	Lat	Lon	Dep	Mod	Aq	RMS	Gap	ELat	ELon	EDEP	DI	EI	AIIn	NSI	M	MW	ML	MN
1	SPL	2017-03-02 16:28:56.07	56.1920	14.7440	15.0	DNK	1.40	288	59.4	46.6	90.5	R				4	3.2	3.2		
2	HFS	2017-03-02 16:28:33.41	45.0	0	0	DNK	1.50	186	5.1	11.2	6.8	L	Q			34	2.4	2.4		
3	NRAO	2017-03-02 16:27:57.67	51.0	0	0	DNK	1.20	253	19.5	40.2	26.9	R				4	2.5	2.5		
4	NRAO	2017-03-02 16:28:46.93	51.0	0	0	DNK	1.10	243	7.6	19.6	31.1	R	Q			20	2.5	2.5		
5	N82	2017-03-02 16:28:01.90	55.0	0	0	DNK	1.20	180	5.9	13.4	0.0	L	E			15	2.3	2.3		
6	FIAO	2017-03-02 16:28:56.07	98.0	0	0	DNK	1.10	198	6.4	7.5	0.0	L	P			34	2.7	2.7		
7	FIAO	2017-03-02 16:30:31.40	98.0	0	0	DNK	2.60	257	44.6	28.3	0.0	L	P			5	2.3	2.3		
8	N82	2017-03-02 16:28:56.07	55.0	0	0	DNK	1.20	194	8.0	18.8	0.0	R	P			10	2.1	2.1		

TIME INTERVAL: 2013.05.17 - 2019.06.17 OPERATOR: PV

During the review process of a seismic bulletin, SEISAN Explorer offers a high level event filtering tool. The interface is shown to the left and offers filtering on multiple parameters. In the figure above the resulting event list is shown, with RMS > 1 AND magnitude > 2, enabling the user to analyze a subset of events in the database in SEISAN Explorer.



In areas with a large number of explosions, such as Scandinavia, SEISAN offers different tools to examine the data for the possibility of it being an explosion. The spectrogram of a seismic record is often useful for the evaluation of the ratio between the P and S wave energy, and an indication of an event being an explosion or not. For multiple event time of day distribution plot are available and to highlight periods with many explosion during midday.

**Future work**

In addition the general development of SEISAN two initiatives are of important to a NDC using SEISAN as part of the daily processing of seismic records:

1. In order to improve the integration of IMS data, work has been initiated to improve the connection between the SEISAN database and VDMs for both waveform and parametric data, the aim is to provide SEISAN as part of ENIAB.
2. A new version of the SEISAN database is currently undergoing beta testing, the new version improves the connection source between data and meta data and apply the user and agency id on phase and amplitude observation level.

References:

- <http://seisan.info>
- Havskov and Ottemoller, Seisan Earthquake analysis software, Seis. Res. Lett., 70, 1999.