NGU REPORT 2023.007

Processing and interpretation of Mareano water column data from the southwestern part of the Norwegian Barents Sea

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NORGES GEOLOGISKE UNDERSØKELSE
- NGU -

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Summary

This study was carried out using multibeam echo sounder data collected during Mareano surveys in 2013, 2015, 2016 and 2020. The data from the surveys have been processed and interpreted to identify natural gas seeps, visible as gas flares, in the water column data. Mapping was carried out in the Hopenbanken, Fingerdjupet basin, Hoop fault complex, Swaen graben and Bjarmalandplattformen areas of the southern Barents Sea. The subsurface geology consists of eroded sediments from Jurassic to middle Triassic age. The shallowest area is on Sentralbanken High, with the seafloor deepening towards 500 m in the Bear Island Trough. The following results were obtained:

- Processing and interpretation of water column data from the study area in the southern Barents Sea using Fledermaus Midwater software indicates 357 flares of varying sizes and confidence levels.
- Flares are categorized according to the standard methods used in Mareano and other projects.
- 36 flares with a magnitude higher than 4 were identified, thus representing ~10% of the flares.

Keywords		
Water Column	Gas Flare	Swaen Graben
Multibeam	Barents Sea	Bjarmelandplatformen
Hopenbanken	Fingerdjupet basin	Hoop Fault complex

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1. INTRODUCTION

Marine methane vents and cold seeps are widespread on continental margins, including the Barents Sea (Skarke et al., 2014; Chand and Thorsnes, 2020). Active seepage on the continental shelf is commonly associated with underlying oil and gas reservoirs, trapped gas under gas hydrates, and dissociation of gas hydrate (Milkov and Sassen, 2003). These seepages can be observed as flares of disturbances in the water column on echosounder data. Detection of gas flares from marine methane vents and cold seeps can be efficiently carried out using multibeam echosounders (Urban et al., 2017).

This study is carried out using multibeam echo sounder data collected during Mareano surveys in 2013, 2015, 2016 and 2020. The surveys included in the study are:

- fosae-2013-D16
- fosae-2013-D17
- fosae-2013-D18
- fosae-2013-D20
- fosae-2013-D22
- fosae-2013-D24
- fosae-2013-D25
- fosae-2015-BH01
- Sverdrup-2016-009
- Sverdrup-2016-010
- Sverdrup-2016-011
- Sverdrup-2016-012
- Sverdrup-2016-014
- fgmg-2020-TR-NS02-NS03-cell001-004

The surveys used Kongsberg EM710 and EM712 systems depending on the years of acquisition and operator for the study areas. The data from the surveys have been processed and interpreted to identify natural gas seeps, visible as gas flares, in the water column data. The data is also used for extracting bathymetry and backscatter as part of the Mareano mapping programme. Bathymetry and backscatter, sub-bottom profiler data and ground truth data using video and sampling are used to create different types of maps, presented by Mareano..

2. STUDY AREA

The study areas lines in the Hopenbanken, Fingerdjupet basin, Hoop fault complex, Swaen graben and Bjarmalandplattformen areas of the southern Barents Sea (Fig. 1) cover large areas and several geological provinces. The water depth ranges from 100 to 500 m.

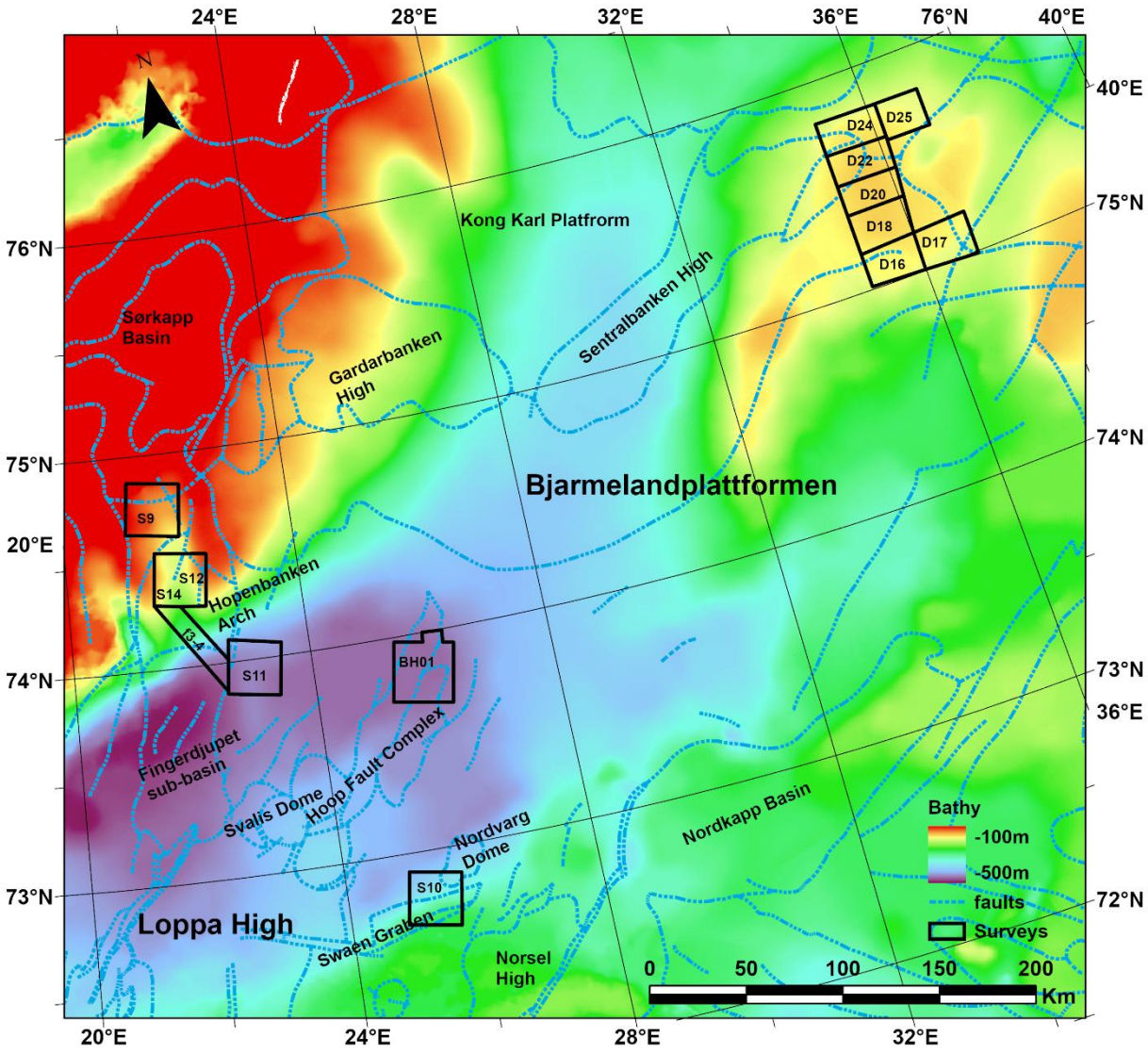
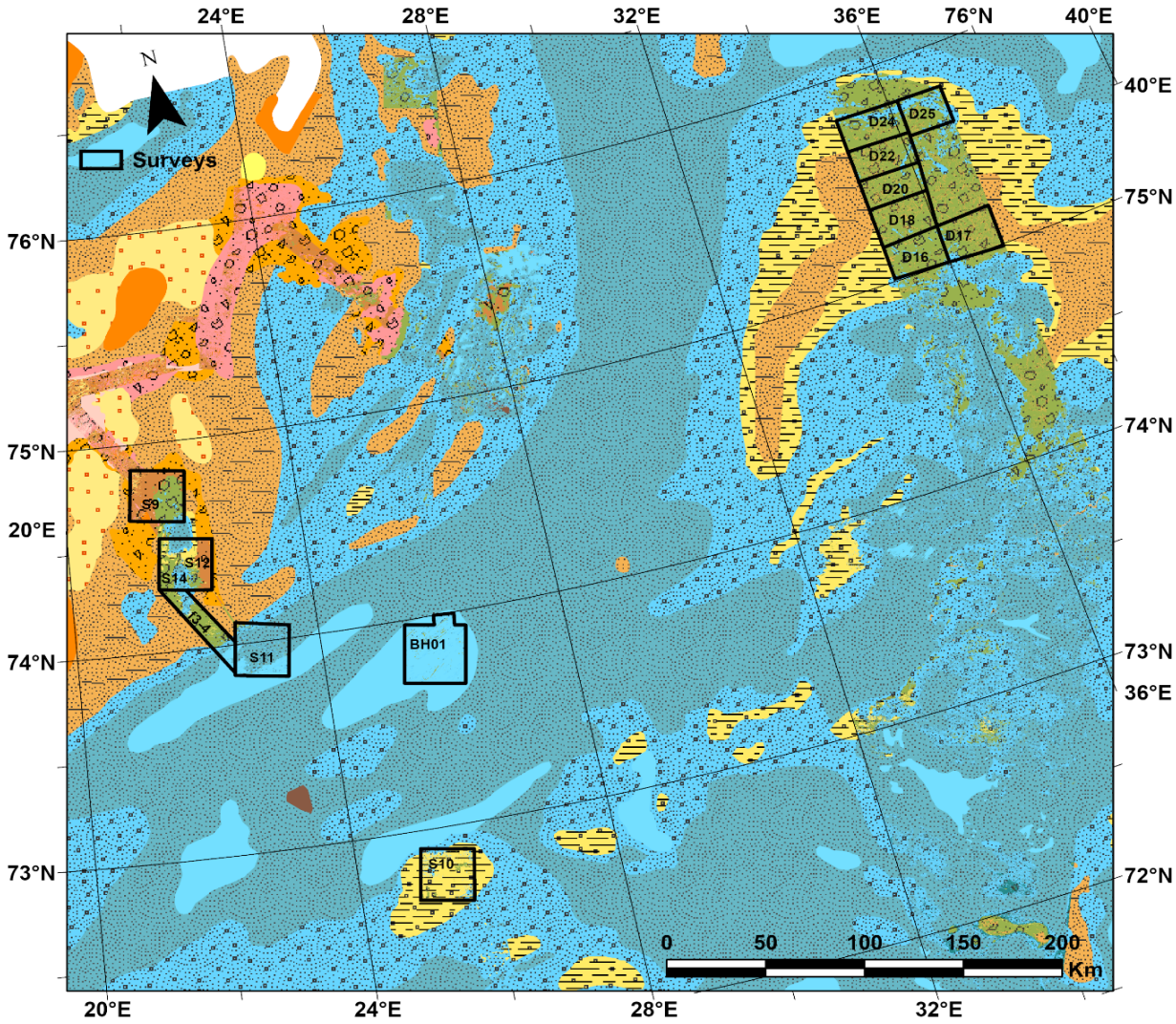


Figure 1. Regional bathymetry map of the Barents Sea showing the major structural boundaries (blue dotted lines) and the locations of various surveys (black polygons). D17: fosae-2013-D17, D18: fosae-2013-D18, D20: fosae-2013-D20, D22: fosae-2013-D22, D24: fosae-2013-D24, D25: fosae-2013-D25, BH01: fosae-2015-BH01, S9: Sverdrup-2016-009, S10: Sverdrup-2016-010, S11: Sverdrup-2016-011, S12: Sverdrup-2016-012. S14: Sverdrup-2016-014, f3-4: fgmg-2020-TR-NS02-NS03-cell001-004.

2.1 Sediment Classification

The sediments at the seafloor of the study area have been classified using multibeam bathymetry and backscatter, sub-bottom profiler, ground truthing samples from gravity/multicore and video observations. The sediments range from muddy (bluish colours) to gravelly (orange colours) and mixed fine- to coarse-grained (mud, sand, gravel, cobbles and boulders) (Fig. 2).



Clay
Mud
Sandy mud
Muddy sand
Sand
Gravelly sandy mud
Gravelly muddy sand
Gravelly sand
Muddy sandy gravel
Sandy gravel
Gravel
Sand, gravel and cobbles
Sand, gravel, cobbles and boulders
Gravel, cobbles, boulders
Cobbles and boulders
Mud and sand with gravel, cobbles and boulders
Compacted sediments or sedimentary bedrock
Thin or discontinuous sediment cover on bedrock. Sediments varying grain size

Figure 2. Detailed sediment grain-size map based on various datasets (both regional and overview). Background map: www.ngu.no.

3. METHODS

3.1 Multibeam

Kongsberg EM710 and EM712 multibeam systems were used by Fugro and FFI to acquire data from the study areas. Both EM710 and EM712 multibeam echosounders can record water column data. The operating frequencies are comparable, and they use 70-100 kHz frequency range. As a rule, features smaller than the size of one fourth the wavelength cannot be resolved (Sheriff, 1980). Hence, only features larger than 1 meter in diameter can be theoretically detected using the EM710 and EM712 system at 120 m water depths. Since the water column data recorded by the systems work on the principle of backscattering, these systems can be used for detection of active gas seeps, and also detection of fauna even though they are of smaller sizes compared to spatial resolution limits. The presence of fish schools (air in bladder) can easily be identified and is hence useful to estimate the energy loss in the water column during detailed backscatter processing. More diffuse clouds in the water column are assigned to plankton. Indications of mammals are seen as large, single reflections, often associated with hyperbolic reflections.

3.2 Fledermaus Software

FlederMaus (FM) Midwater package was used to process water column data for detecting and analysing gas anomalies. The data was loaded in FM Midwater along with navigation (*.all) and converted to GWC files. Special care was taken to go through the noisy lines to avoid missing flares. It is concluded that only weak flares might have been missed through this process.

Similar water column anomalies collected in other areas have been ground truthed confirming the feasibility of this method (Chand et. al. 2012a, 2012b, 2016; Chand and Thorsnes, 2020). During interpretation, the following procedure was used:

1. The depth range was adjusted to maximise the vertical display of the line (FMM).
2. The display was adjusted to 1:1 horizontal display (FMM).
3. The colour range was adjusted to the dynamic range of signals in the water column, optimizing the display of water column features (FMM). Here, we used different ranges based on the system and general loss in the water column through visual inspection. The range is kept constant for the whole survey to avoid any consistency related issues.
4. The data were inspected using the R-stack water column view, and the stacked fan water column view.
5. The locations of gas flares were determined using the GeoPick function in FMM.

The water column data were evaluated in parallel (along-track) and perpendicular (across-track) directions to the track lines for identifying anomalies. The coordinates, time of acquisition, water

depth and height of largest three gas flares above and equal to magnitude 3 were recorded, along with the survey name and line ID. A subjective assessment of the apparent magnitude has been assigned (Table 1). A confidence estimate is provided for codes 1-5. The maximum confidence for visual classification is 90%. A confidence of 100% is reserved for gas flares where gas bubbles have been observed by video/photo inspection or measured using gas sniffers, or where authigenic carbonate crusts have been observed. Very uncertain, but still possible gas flares have been assigned 10% confidence.

Table 1. Codes used for assessment of magnitude, and confidence intervals.

Code	Description	Confidence %
1	Weak gas flare	10 – 100
2	Medium strong gas flare	10 – 100
3	Strong gas flare	10 – 100
4	Very strong gas flare	10 – 100
5	Giant gas flare	10 – 100

Generally, the recognition of gas flares is based on two criteria – the bubbles have higher backscatter strength than the ambient noise in the water column data, and the objects with higher backscatter strength form characteristic patterns in the water column. Under ideal conditions, gas plumes may be observed as flare-shaped objects which start at the seabed and become narrower until they disappear at least 50-100 m above the seabed. If currents are sufficiently strong, the flares will be deflected. The identification of gas flares may be complicated due to several factors, such as high ambient (periodic or random) noise, fish schools, high density of plankton, strong and/or irregular currents, and sub-optimal intersection of the multibeam swath with the gas flare (i.e., covering only part of the flare).

The MBE data can also be used to derive the seafloor reflection (i.e., backscatter) properties which will indirectly give an indication of sediment type/grain size and/or hardness of the sea bottom. The FM Geocoder package was used to process the MBE data for backscatter.

4. RESULTS

4.1 Water Column

Several gas flares have been reported earlier from the southern Barents Sea (Andreassen et al., 2017, Chand et al., 2012b, 2016; Nixon et al., 2019). The flares occur randomly in most areas and are linked to subsurface fluid flow connected to deeper hydrocarbon sources and structural and stratigraphic boundaries (Chand et al.,2012b, 2016; Nixon et al., 2019). The subsurface of

the area indicates eroded old sedimentary rocks occurring at the seafloor or pinching out close to the seafloor (NPD, 2018). The present study area is covered by surveys carried out in 2013, 2015, 2016 and 2020 by Fugro and FFI. The surveys are named as fosae-2013-D16, fosae-2013-D17, fosae-2013-D18, fosae-2013-D20, fosae-2013-D22, fosae-2013-D24, fosae-2013-D25, fosae-2015-BH01, Sverdrup-2016-009, Sverdrup-2016-010, Sverdrup-2016-011, Sverdrup-2016-012, Sverdrup-2016-014, fgmg-2020-TR-NS02-NS03-cell001-004. The data includes EM710 and EM712 water column measurements, and the combined results from the water column data analysis of all the survey areas are shown in Fig. 3.

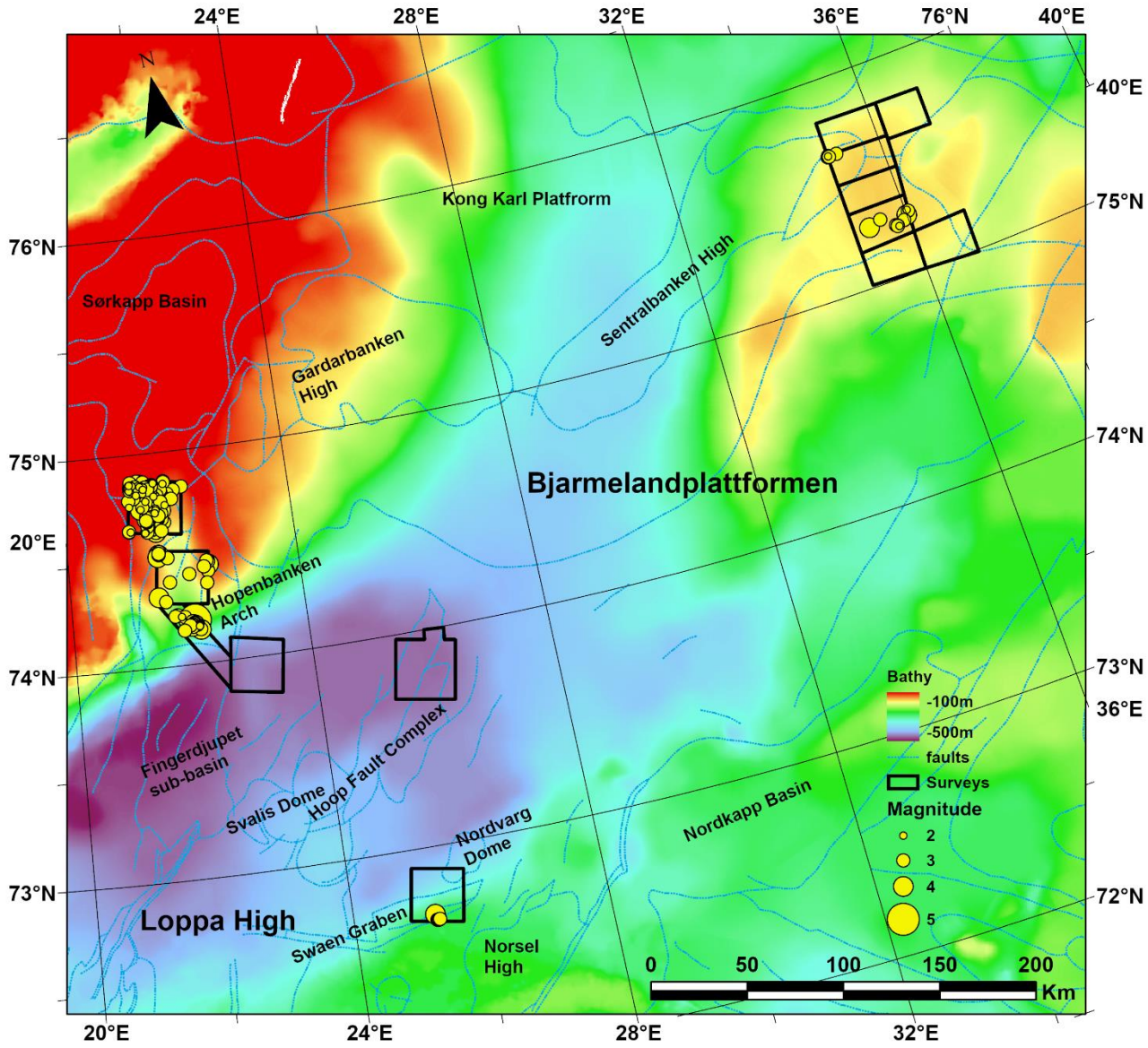


Figure 3. Identified flares and their magnitude, shown on a regional bathymetry map.

4.1.1 Fosae-2013-D16

The fosae-2013-D16 survey consists of 510 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. No flares were found in the data.

4.1.2 Fosae-2013-D17

The fosae-2013-D17 survey consists of 669 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. No flares were found in the data.

4.1.3 Fosae-2013-D18

The fosae-2013-D18 survey consists of 555 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 10 flares were found in the data (Table 2). Two flares of size 4 are shown on in Figs. 4 & 5.

Table 2. Details of flares identified from Survey Area fosae-2013-D18

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
5588	75.289606	35.509627	-157.00	110.00	01/11/2014 15:54:01	3	70
5590	75.290312	36.025241	-149.00	90.00	01/11/2014 16:57:42	2	50
5611	75.284432	36.042243	-158.00	122.00	01/13/2014 8:48:21.9	3	70
5641	75.270783	35.280927	-160.00	135.00	01/14/2014 0:25:04.3	4	80
5647	75.268382	35.998678	-155.00	100.00	01/14/2014 3:41:52.9	4	80
5680	75.250259	35.917076	-157.00	85.00	01/14/2014 18:43:15.2	3	70
5700	75.240576	35.747877	-164.00	80.00	01/15/2014 4:10:12.8	3	70
5717	75.234802	35.772134	-162.00	85.00	01/15/2014 12:34:51.5	3	70
5717	75.234280	35.771746	-163.00	90.00	01/15/2014 12:34:49.9	3	70
5734	75.230376	35.802604	-154.00	25.00	01/19/2014 11:52:47.1	2	70

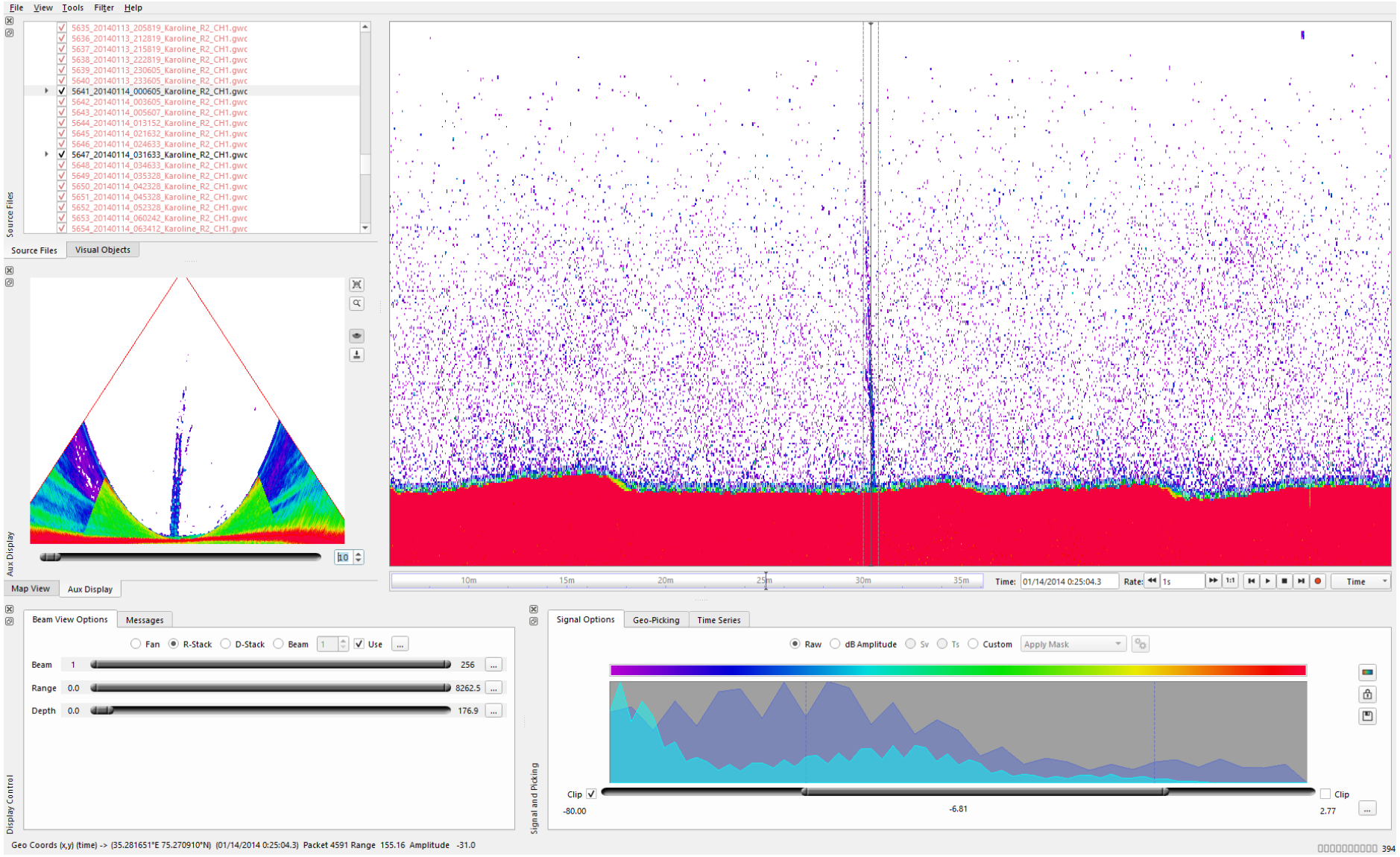


Figure 4. Gas flare from line 5641, fosae-2013-D18 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

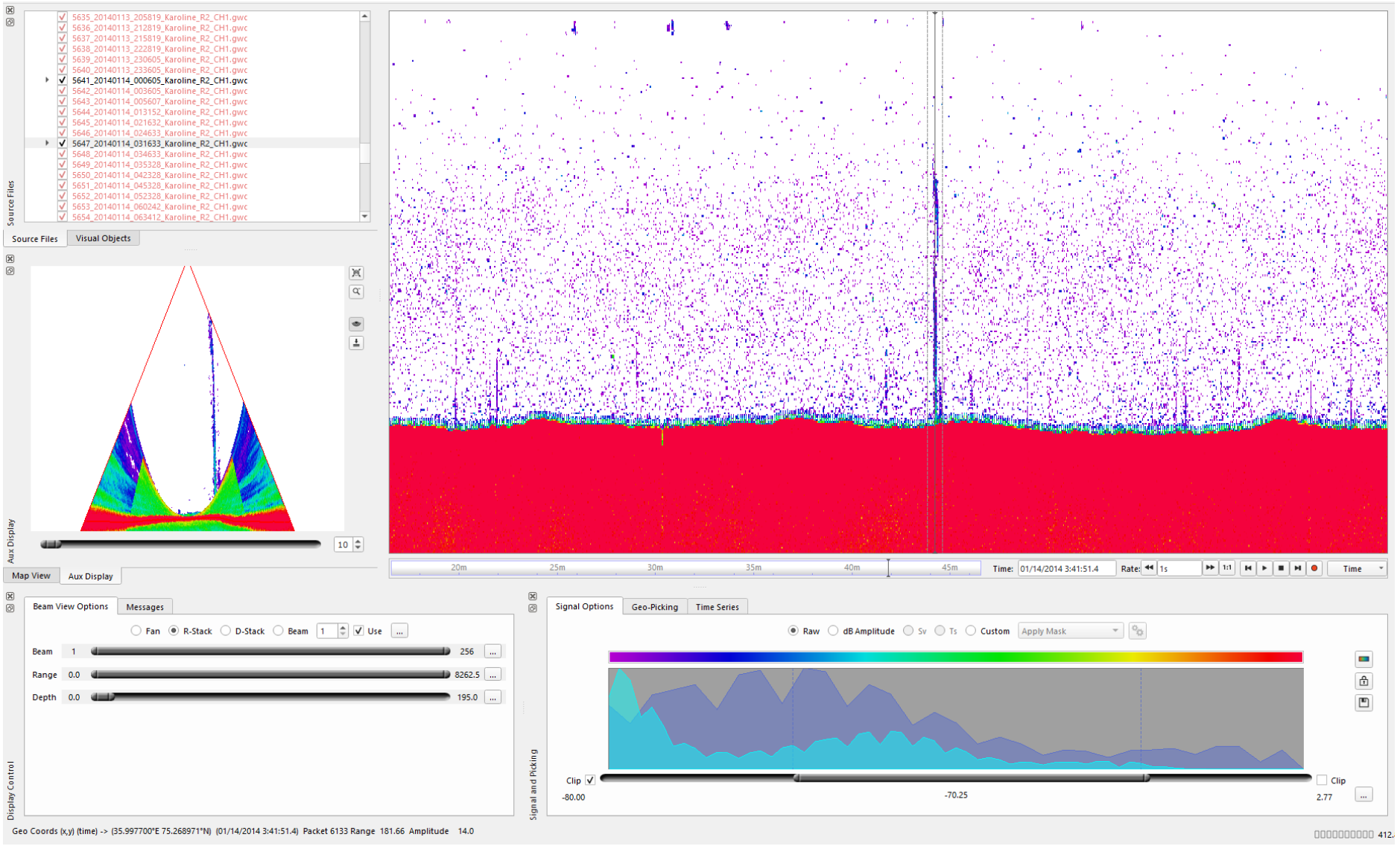


Figure 5. Gas flare from line 5647, fosae-2013-D18 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

4.1.4 Fosae-2013-D20

The fosae-2013-D20 survey consists of 560 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. No flares were found in the data.

4.1.5 Fosae-2013-D22

The fosae-2013-D22 survey consists of 466 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 8 flares were found in the data (Table 3).

Table 3. Details of flares identified from Survey Area fosae-2013-D22.

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
4301	75.648104	34.999097	-163.00	100.00	10/06/2013 08:44:03	3	70
4301	75.647527	34.999747	-166.00	85.00	10/06/2013 08:44:13	2	50
4311	75.645442	35.158324	-163.00	100.00	10/06/2013 13:47:13	3	70
4311	75.645192	35.158028	-163.00	126.00	10/06/2013 13:47:15	3	70
4312	75.644427	34.989302	-165.00	95.00	10/06/2013 14:10:52	3	60
4312	75.644412	34.994488	-163.00	100.00	10/06/2013 14:11:26	3	70
4312	75.644188	35.014419	-166.00	100.00	10/06/2013 14:13:38	3	70
4312	75.643943	35.015133	-166.00	80.00	10/06/2013 14:13:43	3	60

4.1.6 Fosae-2013-D24

The fosae-2013-D24 survey consists of 611 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 37 flares were found in the data (Table 4). Two flares of sizes 4 are shown on in Figs. 6 & 7.

Table 4. Details of flares identified from Survey Area fosae-2013-D24.

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
2534	75.792511	34.973397	-182.00	35.00	08/08/2013 23:18:55	2	60
2534	75.792831	34.981979	-182.00	55.00	08/08/2013 23:19:54	2	70
2534	75.793233	34.988422	-181.00	75.00	08/08/2013 23:20:35	3	80
2546	75.7906409	34.9797802	-182.00	60.00	08/09/2013 04:23:00	3	70
2546	75.7897894	34.9839125	-184.00	72.00	08/09/2013 04:23:28	3	70
2546	75.7906795	34.9849429	-181.00	35.00	08/09/2013 04:23:34	2	60
2546	75.7904346	34.9855984	-183.00	45.00	08/09/2013 04:23:39	3	60
2546	75.7890727	35.0052685	-178.00	50.00	08/09/2013 04:25:48	2	60
2546	75.7893765	35.0063668	-178.00	55.00	08/09/2013 04:25:55	3	70
2546	75.7895765	35.0076498	-179.00	110.00	08/09/2013 04:26:04	3	70
2638	75.756571	35.875128	-178.00	85.00	08/11/2013 18:38:51	3	70
2951	75.687066	35.108201	-167.00	110.00	08/17/2013 5:26:48.1	3	80
2951	75.68806	35.104162	-167.00	65.00	08/17/2013 5:27:14.3	3	80
2952	75.6849864	35.14507588	-168.00	50.00	08/17/2013 6:01:24.2	3	70
2952	75.684992	35.14620413	-167.00	110.00	08/17/2013 6:01:31.4	3	80
2952	75.6847652	35.14870398	-168.00	105.00	08/17/2013 6:01:48.1	3	80
2952	75.6845245	35.14913483	-167.00	80.00	08/17/2013 6:01:51.2	3	80
2952	75.6846914	35.15015118	-168.00	62.00	08/17/2013 6:01:56.9	3	70
2963	75.681825	35.153999	-166.00	100.00	08/17/2013 10:51:17.3	3	80

2966	75.676721	36.095991	-162.00	70.00	08/17/2013 12:31:21.2	3	80
2968	75.675463	35.999178	-160.00	65.00	08/17/2013 13:12:23.	3	80
2968	75.67581	35.981597	-162.00	75.00	08/17/2013 13:14:56.4	3	80
2968	75.675359	35.980758	-162.00	55.00	08/17/2013 13:15:05.1	2	70
2974	75.678747	34.995468	-177.00	70.00	08/17/2013 15:48:24.9	3	70
2974	75.677761	35.027241	-171.00	150.00	08/17/2013 15:51:46.7	4	80
2974	75.677538	35.027168	-170.00	130.00	08/17/2013 15:51:46.7	4	80
3092	75.664657	35.626059	-166.00	40.00	08/21/2013 19:33:11.7	2	70
3092	75.663745	35.628692	-165.00	60.00	08/21/2013 19:33:30.5	3	80
3092	75.66374	35.62957	-164.00	50.00	08/21/2013 19:33:36.0	3	70
3100	75.661527	35.085421	-168.00	50.00	08/21/2013 23:03:09.8	3	80
3101	75.660855	35.497935	-166.00	60.00	08/21/2013 23:48:27.9	3	70
3101	75.660624	35.498666	-166.00	95.00	08/21/2013 23:48:33.4	3	80
3101	75.659652	35.499624	-163.00	130.00	08/21/2013 23:48:43.0	3	80
3114	75.6591118	34.9768342	-168.00	115.00	08/22/2013 4:16:52.6	3	70
3114	75.6587732	35.084865	-169.00	70.00	08/22/2013 4:30:56.8	2	70
3114	75.6582978	35.0861944	-168.00	130.00	08/22/2013 4:31:07.6	3	80
3114	75.6573015	35.1311966	-168.00	80.00	08/22/2013 4:36:57.5	4	80

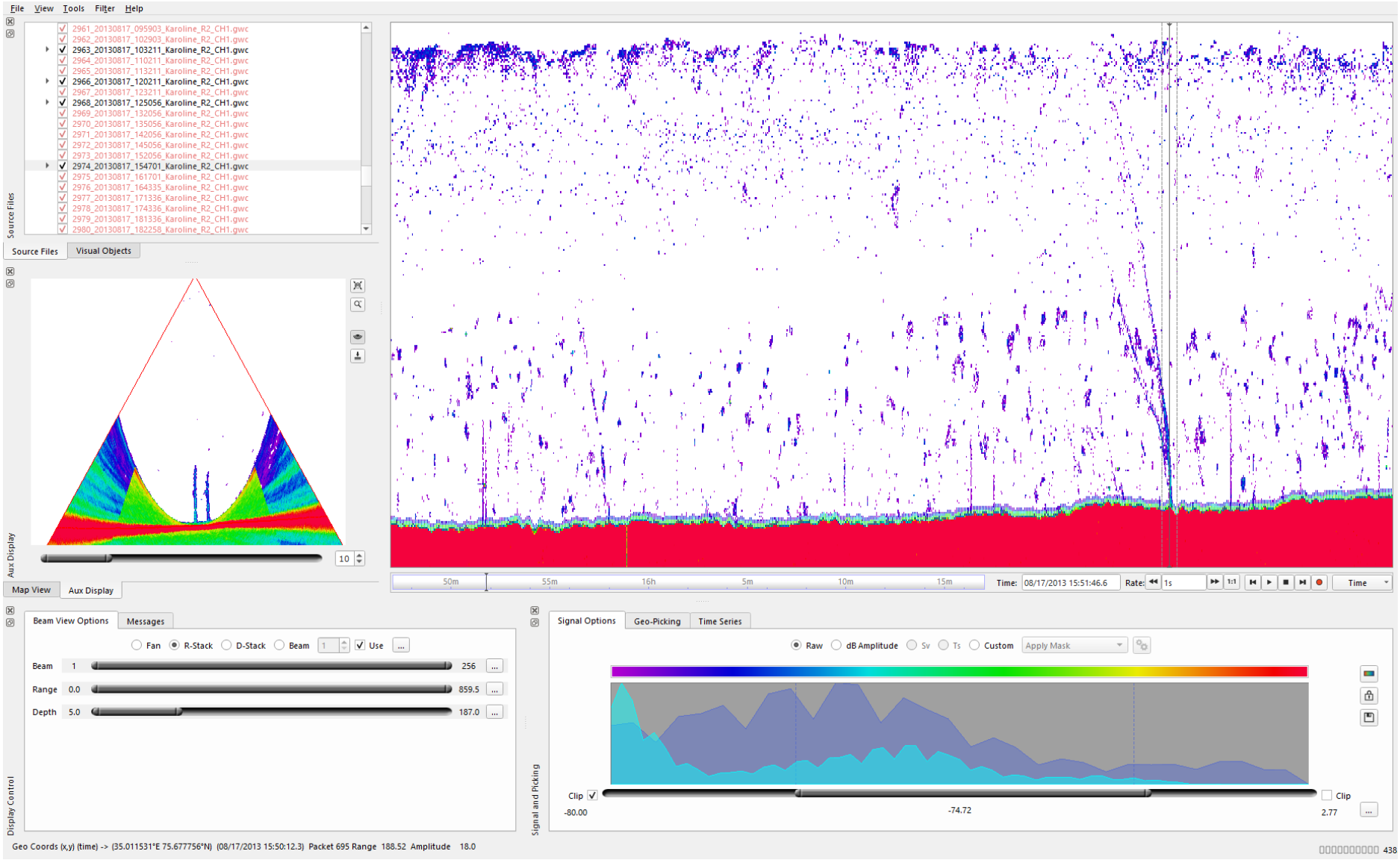


Figure 6. Gas flare from line 2974, fosae-2013-D24 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

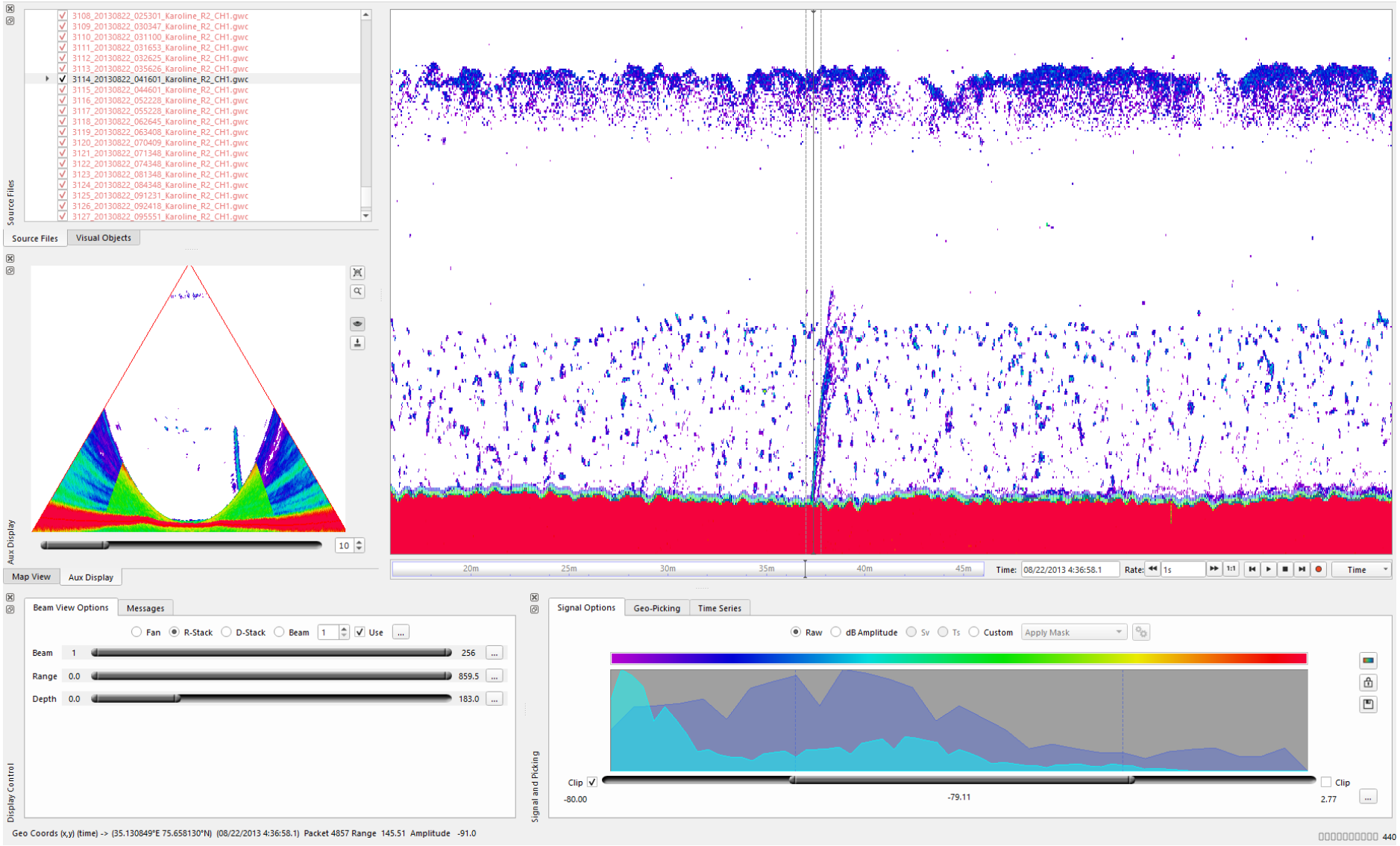


Figure 7. Gas flare from line 3114, fosae-2013-D24 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

4.1.7 Fosae-2013-D25

The fosae-2013-D25 survey consists of 503 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 93 flares were found in the data (Table 5). Nine flares of sizes 4 are shown on in Figs. 8 -16.

Table 5. Details of flares identified from Survey Area fosae-2013-D25.

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
3045	75.682136	36.447911	-165.00	76.00	08/20/2013 22:17:18.7	3	80
3045	75.667973	36.439972	-168.00	45.00	08/20/2013 22:24:23.5	3	80
3245	75.675548	36.205438	-164.00	70.00	08/24/2013 11:24:54.9	2	60
3245	75.675184	36.182083	-159.00	50.00	08/24/2013 11:27:15.4	3	80
3281	75.6844777	36.5575646	-175.00	60.00	08/25/2013 5:21:13.0	2	60
3281	75.6848058	36.5542183	-178.00	100.00	08/25/2013 5:21:42.3	2	60
3281	75.6855383	36.5527009	-176.00	67.00	08/25/2013 5:21:54.1	3	70
3281	75.6850158	36.552151	-176.00	55.00	08/25/2013 5:21:59.9	3	70
3281	75.6851576	36.5513094	-178.00	160.00	08/25/2013 5:22:06.9	5	90
3281	75.6855922	36.5497725	-176.00	40.00	08/25/2013 5:22:19.8	3	70
3281	75.6854653	36.5490655	-175.00	90.00	08/25/2013 5:22:26.3	3	80
3282	75.686724	36.308488	-161.00	50.00	08/25/2013 5:58:11.1	3	70
3285	75.6873794	36.5406973	-174.00	70.00	08/25/2013 9:43:53.6	2	60
3285	75.6872696	36.5412968	-174.00	80.00	08/25/2013 9:43:58.4	3	70
3285	75.686856	36.5417597	-174.00	80.00	08/25/2013 9:44:02.1	3	80
3285	75.6861282	36.5455507	-175.00	60.00	08/25/2013 9:44:35.5	2	60
3285	75.6865531	36.54619	-177.00	145.00	08/25/2013 9:44:42.9	4	80
3285	75.6866675	36.5473212	-176.00	90.00	08/25/2013 9:44:53.1	4	80
3285	75.6862634	36.5489102	-176.00	80.00	08/25/2013 9:45:07.5	4	80
3285	75.6863951	36.5507666	-176.00	90.00	08/25/2013 9:45:24.7	3	70
3285	75.6855516	36.5527882	-174.00	30.00	08/25/2013 9:45:42.4	3	60

3294	75.6874039	36.5408723	-174.00	40.00	08/25/2013 12:08:38.4	3	60
3294	75.687321	36.5412213	-174.00	41.00	08/25/2013 12:08:41.0	3	60
3294	75.686889	36.5418221	-174.00	70.00	08/25/2013 12:08:44.7	3	80
3294	75.6869856	36.5447784	-175.00	50.00	08/25/2013 12:09:02.7	2	60
3294	75.686142	36.5456681	-175.00	60.00	08/25/2013 12:09:08.0	2	60
3294	75.6865539	36.5462469	-176.00	110.00	08/25/2013 12:09:12.2	3	80
3294	75.6866936	36.5472512	-175.00	60.00	08/25/2013 12:09:18.6	3	80
3294	75.6867823	36.5490452	-174.00	70.00	08/25/2013 12:09:29.3	3	80
3294	75.6864059	36.5506287	-175.00	72.00	08/25/2013 12:09:39.4	3	70
3294	75.6853423	36.5521108	-177.00	68.00	08/25/2013 12:09:47.5	3	60
3294	75.685504	36.5530937	-174.00	90.00	08/25/2013 12:09:53.9	3	70
3298	75.688507	36.701194	-174.00	40.00	08/25/2013 13:50:34.3	3	70
3298	75.6881	36.547334	-173.00	110.00	08/25/2013 14:08:44.8	4	90
3298	75.687895	36.540363	-174.00	45.00	08/25/2013 14:09:35.2	3	80
3299	75.689347	36.421797	-166.00	70.00	08/25/2013 14:23:30.3	4	80
3299	75.689115	36.385913	-168.00	72.00	08/25/2013 14:27:42.5	3	70
3299	75.689374	36.383092	-167.00	40.00	08/25/2013 14:28:01.7	3	70
3303	75.690826	36.42002	-168.00	150.00	08/25/2013 15:37:18.1	4	90
3334	75.699823	36.461204	-170.00	140.00	09/01/2013 20:02:05	4	80
3334	75.70053	36.375747	-168.00	60.00	09/01/2013 20:11:29	3	70
3336	75.702488	36.364852	-170.00	105.00	09/01/2013 21:07:55	3	80
3336	75.701929	36.367759	-170.00	40.00	09/01/2013 21:08:14	2	60
3336	75.701575	36.369821	-169.00	55.00	09/01/2013 21:08:28	3	70
3337	75.7023103	36.4585992	-171.00	75.00	09/01/2013 21:18:37	3	70
3337	75.7020647	36.4604493	-167.00	80.00	09/01/2013 21:18:49	3	70
3337	75.7022466	36.4607602	-170.00	100.00	09/01/2013 21:18:51	4	80
3337	75.7024363	36.4606944	-170.00	90.00	09/01/2013 21:18:51	3	80
3337	75.7025202	36.4615129	-170.00	25.00	09/01/2013 21:18:57	3	70
3337	75.701264	36.464841	-167.00	25.00	09/01/2013 21:19:17	2	70

3337	75.7026111	36.4664713	-167.00	25.00	09/01/2013 21:19:31	2	60
3342	75.7030524	36.4617323	-163.00	27.00	09/01/2013 23:49:44	2	60
3342	75.7045394	36.4519069	-165.00	65.00	09/01/2013 23:50:49	3	70
3342	75.7046708	36.4511345	-165.00	50.00	09/01/2013 23:50:54	3	70
3342	75.7047078	36.4489255	-168.00	70.00	09/01/2013 23:51:08	3	70
3342	75.7049854	36.4478084	-168.00	55.00	09/01/2013 23:51:15	3	80
3342	75.7030746	36.443058	-166.00	15.00	09/01/2013 23:51:47	2	70
3342	75.7037073	36.4419725	-169.00	15.00	09/01/2013 23:51:54	2	50
3342	75.7044421	36.3537168	-172.00	25.00	09/02/2013 00:01:37	2	60
3350	75.7074759	36.4609546	-173.00	90.00	09/02/2013 03:26:49	3	80
3350	75.7079384	36.4552247	-173.00	100.00	09/02/2013 03:27:27	3	80
3350	75.7077203	36.4541874	-171.00	50.00	09/02/2013 03:27:34	3	70
3350	75.7071938	36.4536516	-172.00	50.00	09/02/2013 03:27:37	3	70
3350	75.7068027	36.4384576	-172.00	50.00	09/02/2013 03:29:18	3	70
3350	75.7077798	36.4127563	-176.00	90.00	09/02/2013 03:32:10	3	70
3352	75.7110596	36.3841124	-174.00	60.00	09/02/2013 04:29:57	3	60
3352	75.7103536	36.4028179	-170.00	60.00	09/02/2013 04:32:00	3	70
3352	75.7107344	36.4055408	-172.00	130.00	09/02/2013 04:32:20	3	80
3352	75.710189	36.4071486	-173.00	70.00	09/02/2013 04:32:29	3	70
3352	75.7094557	36.4087686	-174.00	60.00	09/02/2013 04:32:37	3	70
3352	75.709625	36.4112762	-177.00	80.00	09/02/2013 04:32:55	3	70
3353	75.708988	36.453609	-172.00	54.00	09/02/2013 04:37:36	3	70
3359	75.710763	36.4087704	-172.00	90.00	09/02/2013 07:09:29	3	70
3359	75.7103864	36.4078125	-171.00	60.00	09/02/2013 07:09:35	2	70
3359	75.7108686	36.4066938	-171.00	110.00	09/02/2013 07:09:43	3	70
3359	75.7104537	36.4048629	-72.00	60.00	09/02/2013 07:09:55	3	70
3359	75.7106751	36.4044287	-171.00	70.00	09/02/2013 07:09:58	3	70
3359	75.7107263	36.4036056	-171.00	70.00	09/02/2013 07:10:03	3	70
3359	75.7105925	36.4026073	-172.00	75.00	09/02/2013 07:10:10	3	70

3359	75.7109529	36.4018545	-172.00	60.00	09/02/2013 07:10:15	3	80
3359	75.7118656	36.4011591	-169.00	50.00	09/02/2013 07:10:20	3	70
3359	75.7111971	36.3993973	-171.00	50.00	09/02/2013 07:10:32	2	60
3359	75.711432	36.398377	-169.00	40.00	09/02/2013 07:10:39	3	70
3359	75.7115284	36.3977744	-170.00	70.00	09/02/2013 07:10:43	3	80
3359	75.7116767	36.3969175	-171.00	40.00	09/02/2013 07:10:49	3	70
3359	75.7111703	36.3855205	-174.00	50.00	09/02/2013 07:12:04	3	70
3359	75.7109059	36.3847829	-175.00	90.00	09/02/2013 07:12:09	3	80
3359	75.7110373	36.3840793	-176.00	90.00	09/02/2013 07:12:14	3	80
3436	75.749719	36.352	-165.00	50.00	09/03/2013 16:58:11	3	60
3478	75.774362	36.524202	-187.00	90.00	09/04/2013 11:40:38	3	80
3478	75.774563	36.524246	-188.00	90.00	09/04/2013 11:40:38	3	80
3478	75.774771	36.524468	-188.00	90.00	09/04/2013 11:40:38	3	80
3478	75.772656	36.641991	-196.00	80.00	09/04/2013 11:53:55	3	80

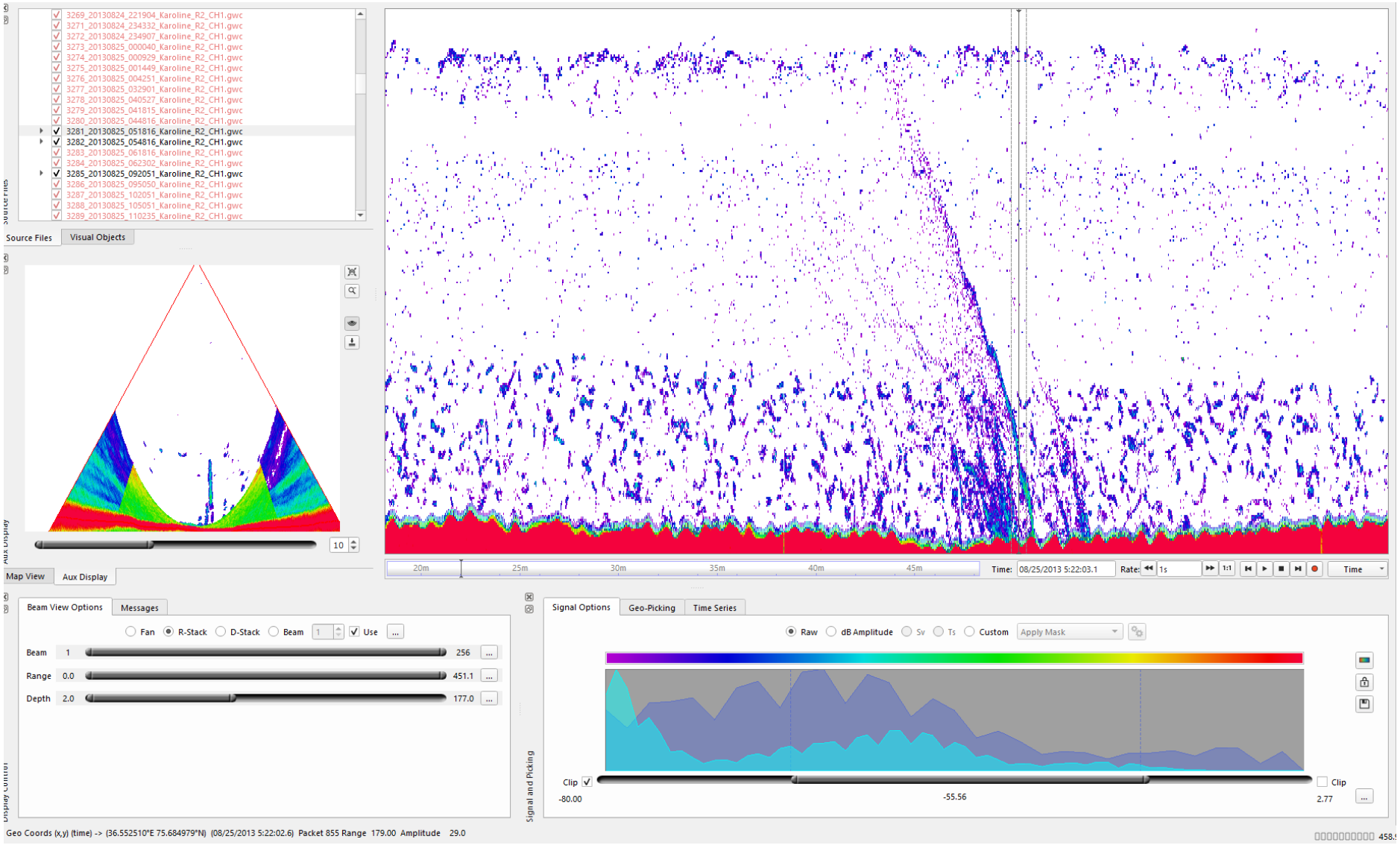


Figure 8. Gas flare from line 3281, fosae-2013-D25 showed on Fan view and stack view. Magnitude 5, Confidence 90%.

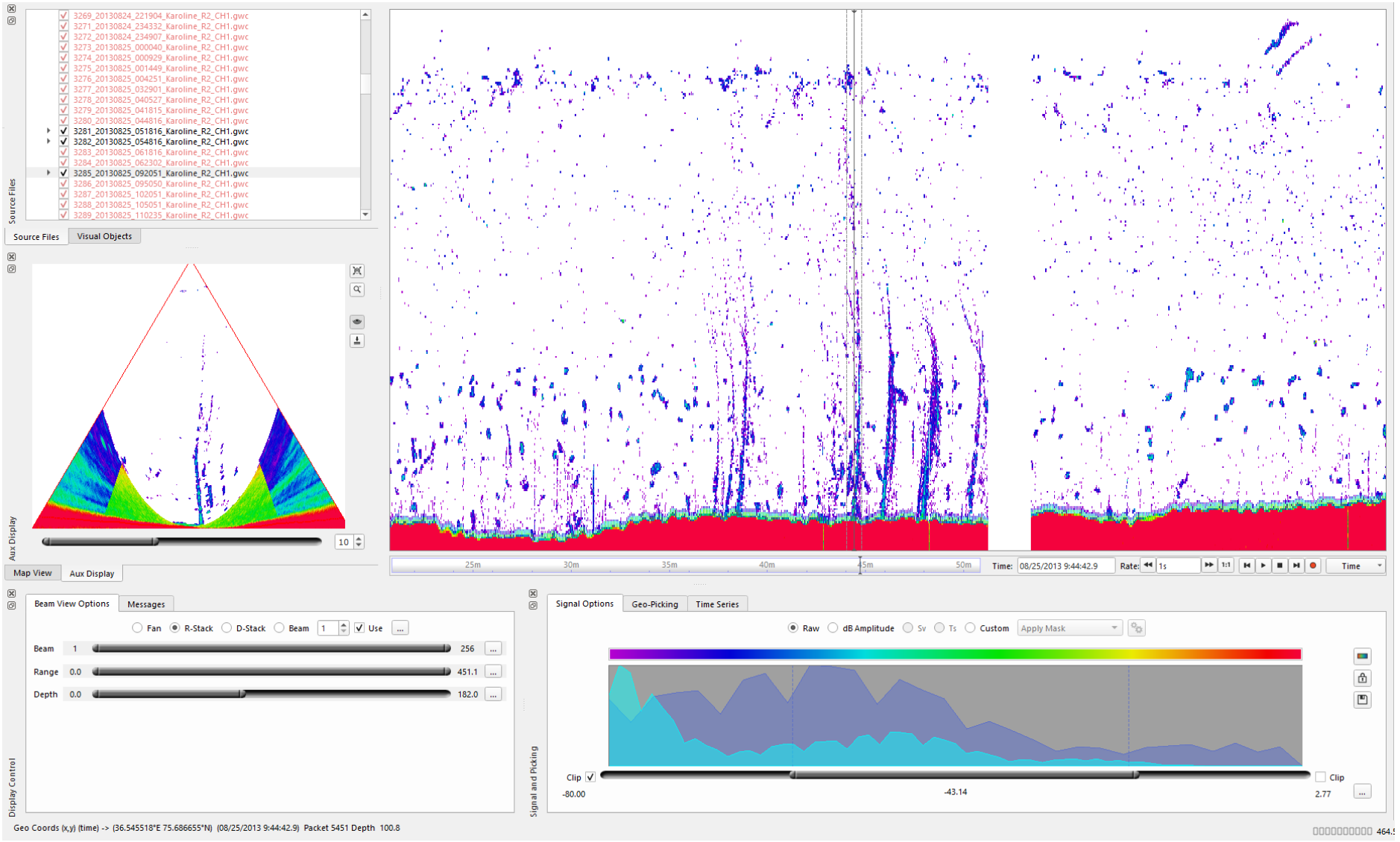


Figure 9. Gas flare from line 3285, fosae-2013-D25 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

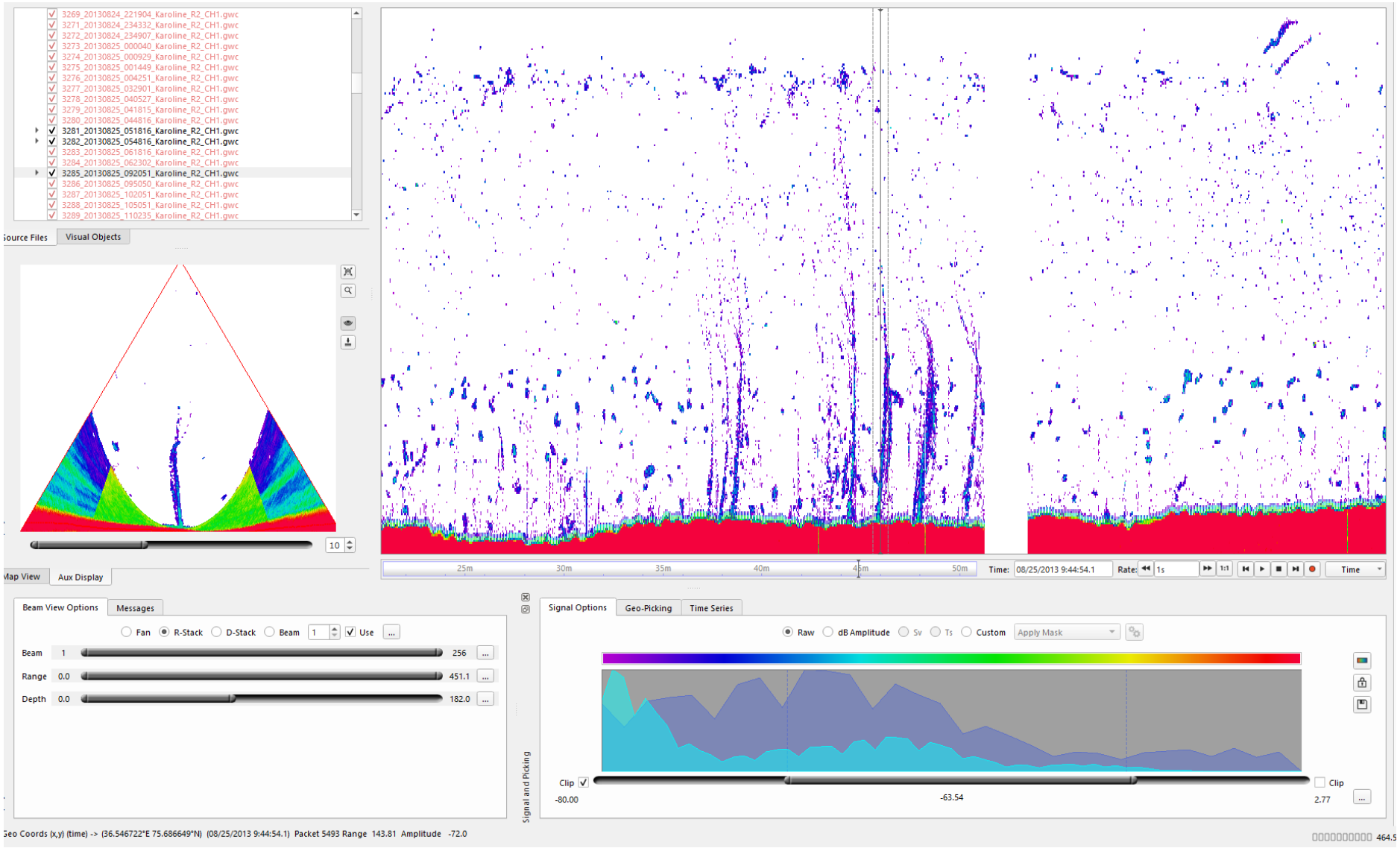


Figure 10. Gas flare from line 3285, fosae-2013-D25 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

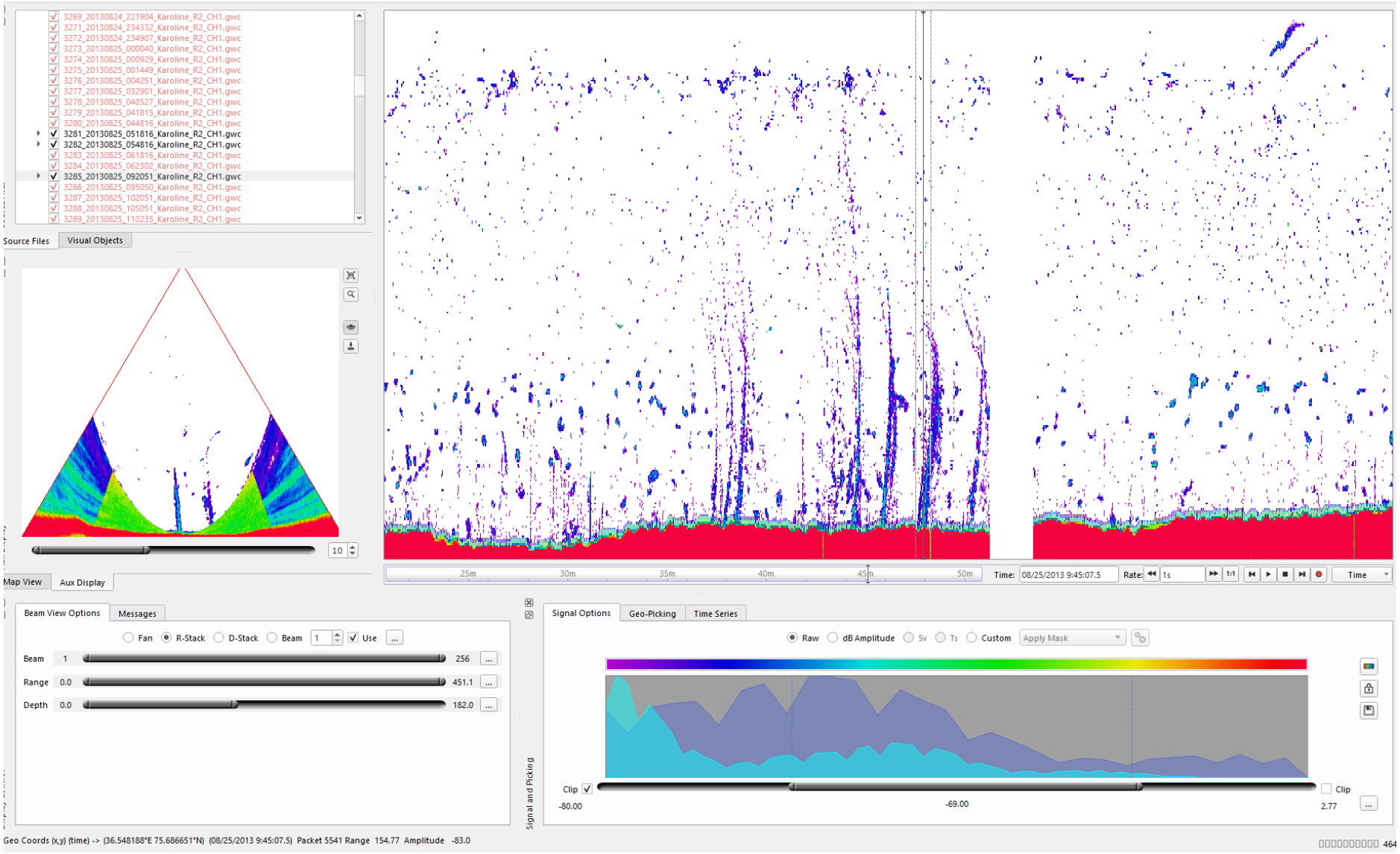


Figure 11. Gas flare from line 3285, fosae-2013-D25 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

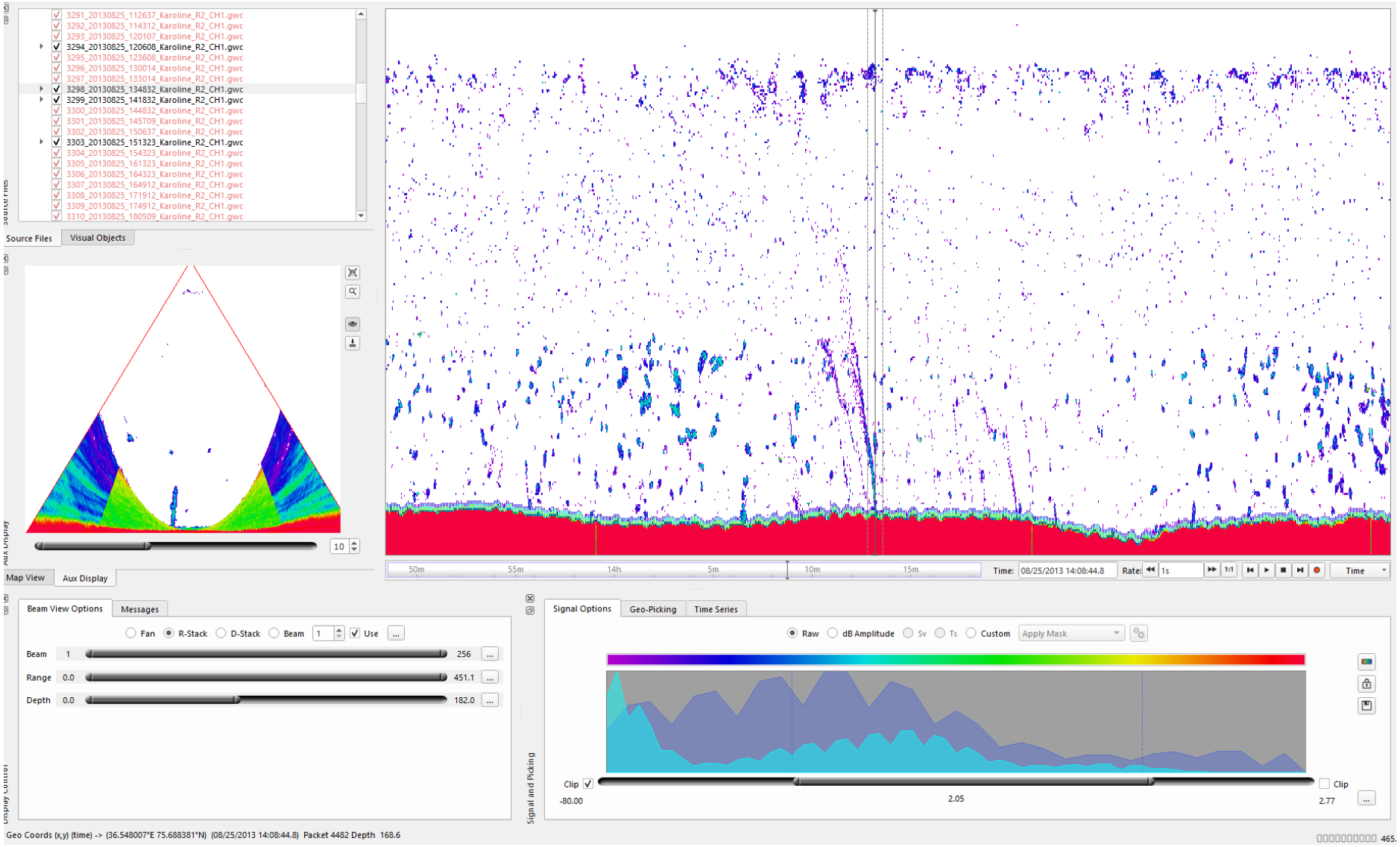


Figure 12. Gas flare from line 3298, fosae-2013-D25 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

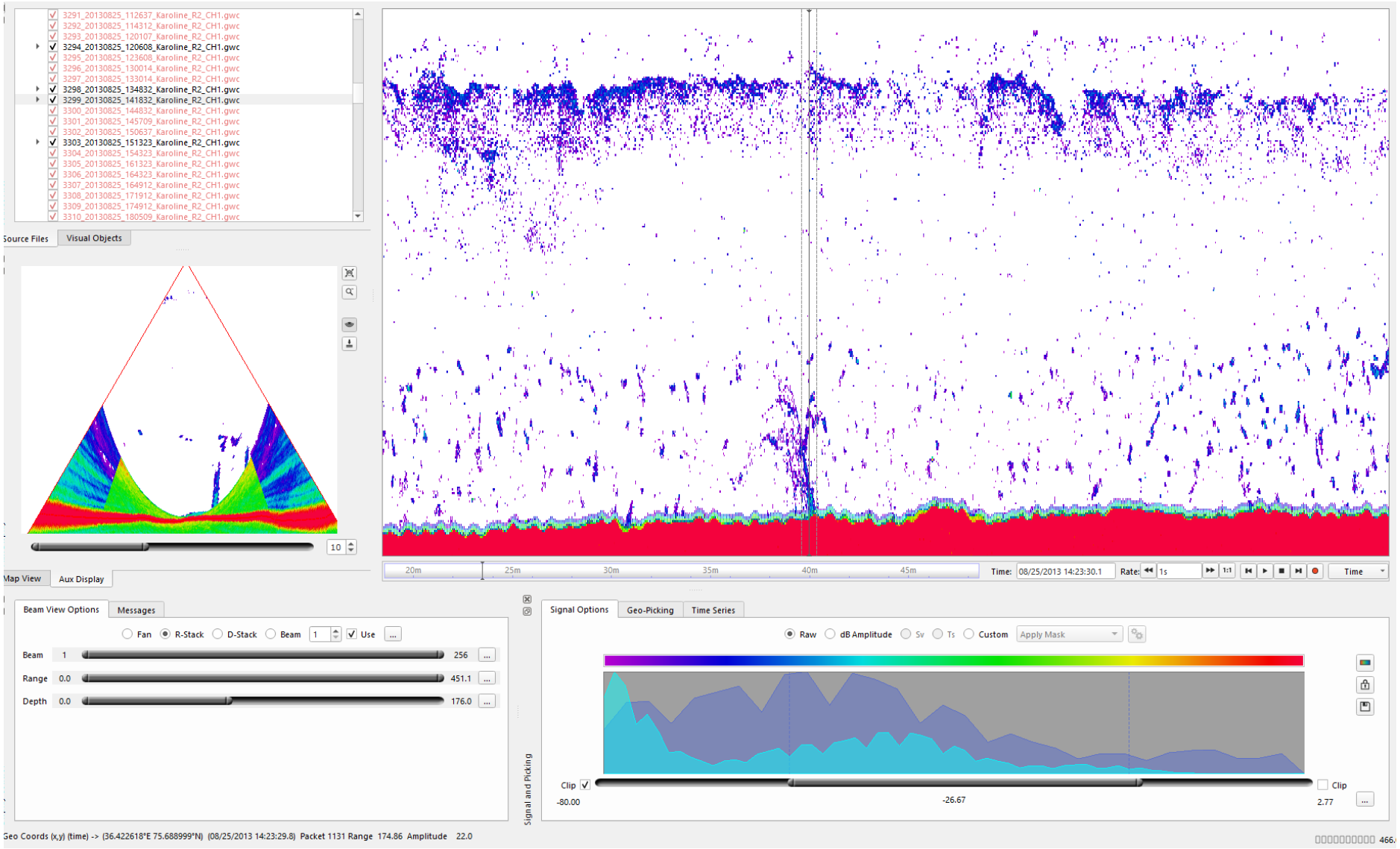


Figure 13. Gas flare from line 3299, fosae-2013-D25 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

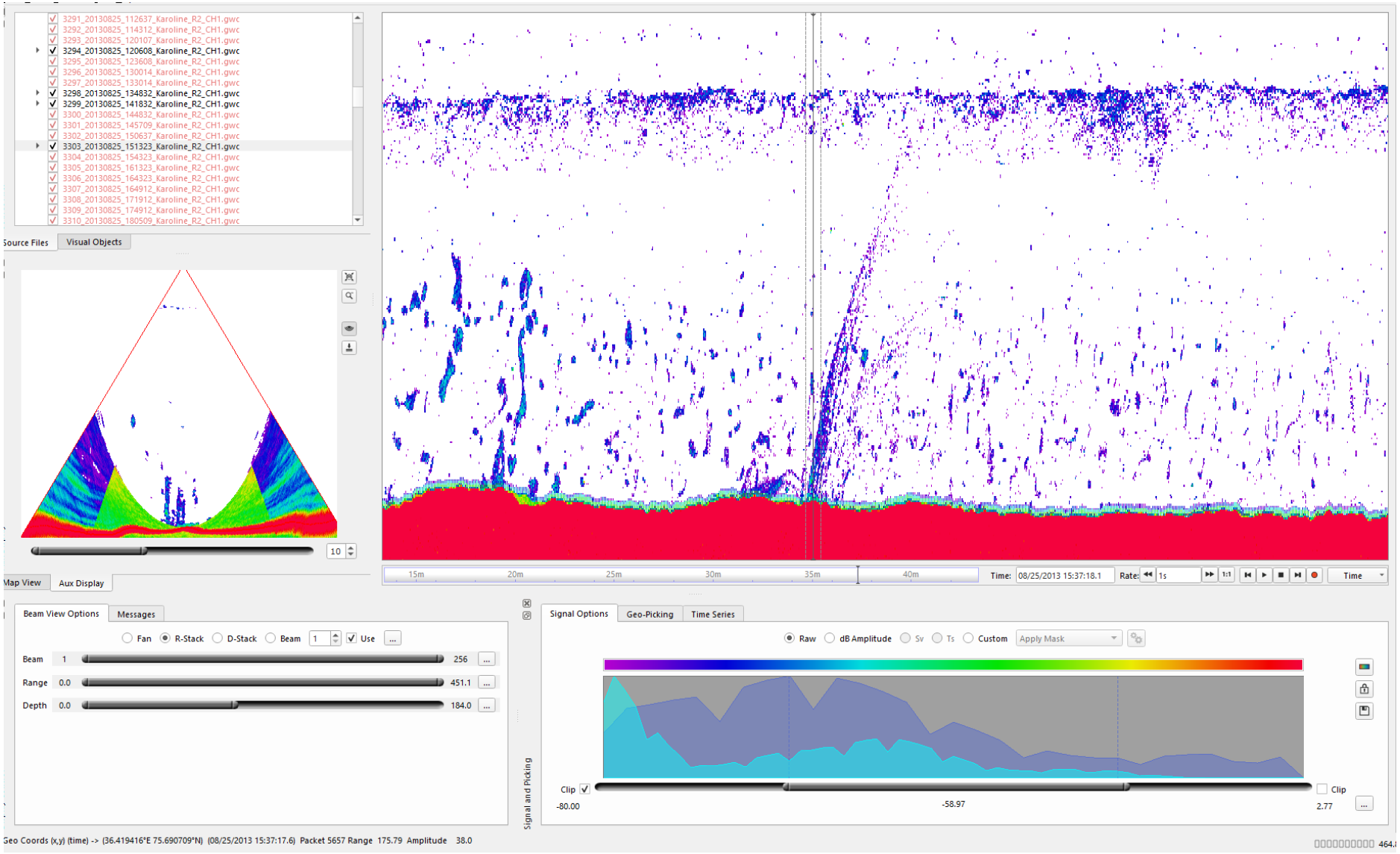


Figure 14. Gas flare from line 3303, fosae-2013-D25 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

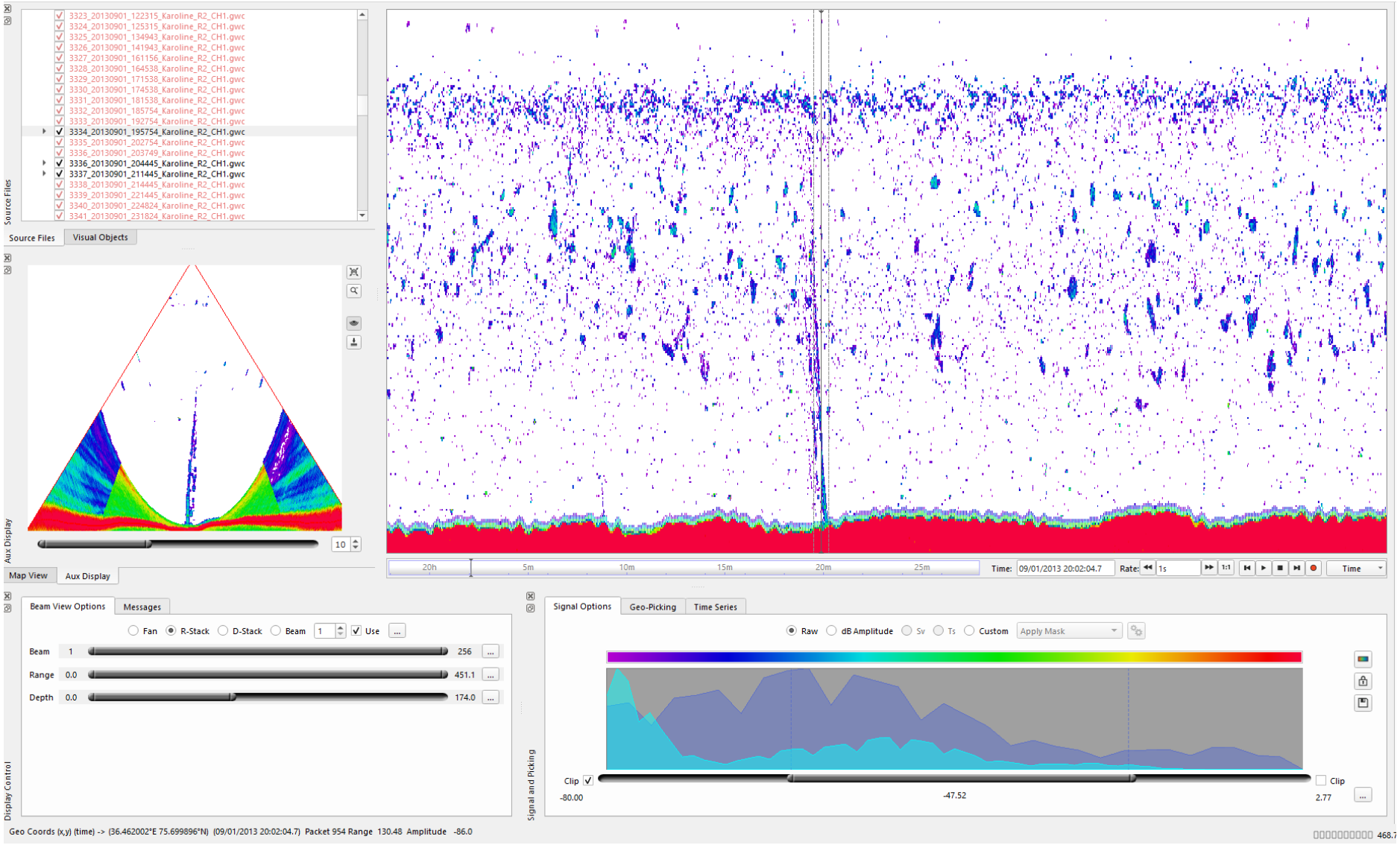


Figure 15. Gas flare from line 3334, fosae-2013-D25 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

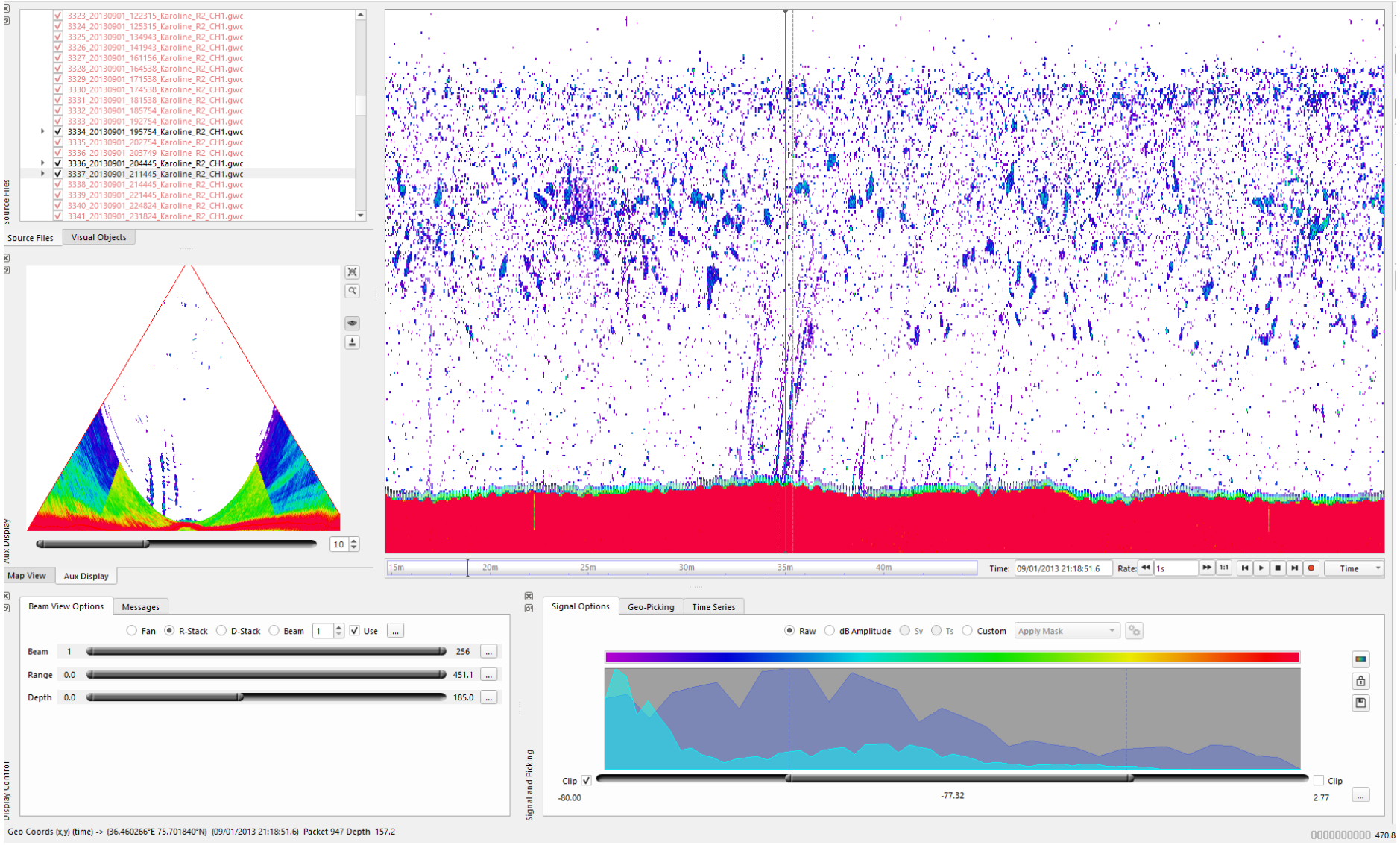


Figure 16. Gas flare from line 3337, fosae-2013-D25 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

4.1.8 Fosae-2015-BH01

The fosae-2015-BH01 survey consists of 412 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. No flares were found in the data.

4.1.9 Sverdrup-2016-009

The Sverdrup-2016-009 survey consists of 693 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 160 flares were found in the data (Table 6). Ten flares of sizes 4 are shown on in Figs. 17 & 26.

Table 6. Details of flares identified from Survey Area Sverdrup-2016-009.

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
12	74.845485	21.196075	-85.00	70.00	02/25/2016 8:01:06.7	3	60
15	74.759719	21.162925	-93.00	70.00	02/25/2016 8:53:10.9	2	50
19	74.644701	21.118157	-95.00	45.00	02/25/2016 10:06:26.7	3	70
19	74.643574	21.114730	-95.00	45.00	02/25/2016 10:07:10.6	3	70
28	74.830367	22.112692	-111.00	50.00	05/01/2016 06:11:51	3	60
69	74.819322	21.960937	-135.00	35.00	10/26/2016 15:41:57.6	3	60
114	74.674703	21.745948	-142.00	130.00	10/27/2016 12:01:31.3	3	50
126	74.804774	21.847243	-142.00	70.00	10/27/2016 17:30:38.6	3	60
146	74.690125	21.705848	-140.00	70.00	10/28/2016 5:53:00.1	3	60
170	74.863782	21.808117	-110.00	70.00	10/28/2016 16:34:44.3	3	60
170	74.861962	21.806342	-110.00	50.00	10/28/2016 16:35:41.8	3	60
170	74.860072	21.803445	-110.00	80.00	10/28/2016 16:36:41.2	3	70
178	74.874930	21.384736	-85.00	50.00	10/28/2016 18:08:06.8	3	50
179	74.876395	21.327444	-83.00	60.00	10/28/2016 18:15:45.5	3	70
184	74.870169	21.440414	-91.00	70.00	10/28/2016 21:54:34.7	3	60
192	74.860427	21.626072	-106.00	50.00	10/29/2016 3:27:37.9	2	60

199	74.872447	21.210096	-78.00	40.00	10/29/2016 7:25:14.1	3	70
204	74.852883	21.594823	-103.00	50.00	10/29/2016 12:55:59.0	3	70
217	74.759037	21.711917	-144.00	50.00	10/30/2016 12:22:07.6	3	70
218	74.707345	21.663401	-145.00	75.00	10/30/2016 12:52:36.3	3	70
224	74.751604	21.691299	-147.00	75.00	10/30/2016 16:41:15.1	3	70
224	74.751172	21.691363	-147.00	75.00	10/30/2016 16:41:27.0	3	70
224	74.751138	21.691829	-147.00	75.00	10/30/2016 16:41:27.0	3	70
225	74.7453147	21.6863265	-147.922	90.00	10/30/2016 16:44:22.4	3	70
225	74.7343483	21.6803715	-152.213	30.00	10/30/2016 16:49:45.2	3	60
225	74.7267509	21.6703565	-155.031	60.00	10/30/2016 16:53:38.7	3	70
225	74.716684	21.660607	-153.244	30.00	10/30/2016 16:58:44.0	3	70
225	74.712831	21.6598628	-153.639	60.00	10/30/2016 17:00:34.5	3	70
225	74.6964291	21.6414288	-139.624	45.00	10/30/2016 17:08:55.2	3	60
225	74.6958118	21.6416745	-137.812	60.00	10/30/2016 17:09:12.8	3	70
225	74.6944509	21.6407761	-137.19	60.00	10/30/2016 17:09:53.1	3	70
225	74.6889713	21.6384863	-132.052	65.00	10/30/2016 17:12:34.1	3	70
227	74.630518	21.584627	-135.00	132.00	10/30/2016 17:41:57.5	4	80
227	74.629109	21.584297	-133.00	85.00	10/30/2016 17:42:38.5	3	70
230	74.825368	21.750641	-120.00	100.00	10/30/2016 20:15:22.3	4	80
230	74.814148	21.738116	-121.00	40.00	10/30/2016 20:21:47.3	3	60
231	74.765754	21.696919	-132.00	50.00	10/30/2016 20:48:10.1	3	60
232	74.734550	21.665712	-156.00	60.00	10/30/2016 21:04:07.8	3	70
232	74.719812	21.651822	-152.00	55.00	10/30/2016 21:11:38.8	3	70
232	74.718766	21.652217	-154.00	80.00	10/30/2016 21:12:10.3	3	70
232	74.717722	21.648035	-152.00	60.00	10/30/2016 21:12:44.7	3	70
233	74.684684	21.619088	-126.00	50.00	10/30/2016 21:29:33.9	3	70
233	74.676173	21.610276	-120.00	35.00	10/30/2016 21:33:56.4	3	70
236	74.674449	21.597970	-122.00	80.00	10/30/2016 22:31:39.8	3	70
239	74.826641	21.737811	-124.00	60.00	10/30/2016 23:49:28.7	3	60

242	74.754989	21.658165	-150.00	50.00	10/31/2016 0:48:08.9	3	60
244	74.7146924	21.6221801	-145.867	65.00	10/31/2016 1:08:43.1	3	70
244	74.68812	21.5944123	-120.718	50.00	10/31/2016 1:22:22.8	3	70
244	74.6733503	21.5835254	-125.328	50.00	10/31/2016 1:29:50.2	3	70
244	74.6713397	21.5814993	-124.925	70.00	10/31/2016 1:30:52.3	3	70
246	74.675473	21.574875	-124.00	45.00	10/31/2016 2:23:43.9	3	70
246	74.675431	21.575541	-124.00	50.00	10/31/2016 2:23:43.9	3	60
248	74.715465	21.611421	-142.00	80.00	10/31/2016 2:44:08.9	3	70
248	74.719577	21.614413	-148.00	70.00	10/31/2016 2:46:13.2	3	70
252	74.785260	21.666306	-132.00	50.00	10/31/2016 4:24:48.8	3	70
252	74.741677	21.627183	-153.00	50.00	10/31/2016 4:47:00.4	2	60
252	74.734965	21.620821	-154.00	45.00	10/31/2016 4:50:25.4	2	60
253	74.731032	21.616116	-154.00	70.00	10/31/2016 4:52:27.1	3	70
253	74.706029	21.593501	-134.00	65.00	10/31/2016 5:05:11.0	3	70
253	74.704342	21.589978	-133.00	70.00	10/31/2016 5:06:06.3	3	70
254	74.677387	21.565230	-122.00	70.00	10/31/2016 5:19:50.9	3	70
255	74.645409	21.523631	-113.00	60.00	10/31/2016 5:58:45.7	3	70
255	74.677062	21.557728	-124.00	65.00	10/31/2016 6:15:08.4	3	60
256	74.721102	21.598029	-138.00	70.00	10/31/2016 6:37:37.3	2	60
258	74.796880	21.667554	-123.00	60.00	10/31/2016 7:16:18.3	3	70
260	74.802404	21.663693	-128.00	90.00	10/31/2016 8:08:43.1	3	70
263	74.687023	21.554773	-115.00	90.00	10/31/2016 9:07:41.6	4	70
278	74.702712	21.533015	-105.00	70.00	10/31/2016 14:15:55.9	3	70
278	74.704683	21.535888	-106.00	70.00	10/31/2016 14:16:59.0	3	70
278	74.710172	21.541941	-113.00	70.00	10/31/2016 14:19:48.3	3	70
283	74.756961	21.576410	-149.00	70.00	10/31/2016 16:23:30.4	3	70
290	74.762462	21.568434	-147.00	70.00	10/31/2016 18:41:45.1	3	70
290	74.764365	21.574414	-148.00	80.00	10/31/2016 18:42:54.8	3	70
291	74.780036	21.588928	-139.00	70.00	10/31/2016 18:50:47.4	3	70

291	74.794649	21.599404	-134.00	70.00	10/31/2016 18:58:16.2	3	70
291	74.798195	21.608785	132.00	60.00	10/31/2016 19:00:17.2	2	50
298	74.662344	21.465850	-101.00	50.00	10/31/2016 21:05:19.2	3	50
298	74.644941	21.450809	-113.00	60.00	10/31/2016 21:14:10.2	3	70
298	74.634859	21.440243	-114.00	60.00	10/31/2016 21:19:19.7	3	70
299	74.663575	21.456907	-96.00	40.00	10/31/2016 21:43:33.6	3	70
301	74.720973	21.512121	-109.00	50.00	10/31/2016 22:12:59.7	3	70
301	74.774244	21.560924	-131.00	40.00	10/31/2016 22:40:08.9	3	70
308	74.750046	21.527556	-135.00	40.00	11/01/2016 00:40:13	3	70
309	74.749143	21.527706	-133.00	40.00	11/01/2016 00:40:39	3	70
309	74.746274	21.522498	-129.00	45.00	11/01/2016 00:42:12	3	70
310	74.713187	21.493259	-94.00	40.00	11/01/2016 00:59:13	3	70
310	74.713151	21.492563	-94.00	40.00	11/01/2016 00:59:15	3	70
312	74.686145	21.464182	-99.00	50.00	11/01/2016 01:13:16	3	60
313	74.667511	21.449808	-94.00	45.00	11/01/2016 01:22:46	3	60
314	74.660837	21.446529	-96.00	50.00	11/01/2016 01:26:07	3	50
317	74.682297	21.450554	-94.00	40.00	11/01/2016 02:12:56	3	70
317	74.686570	21.455303	-101.00	45.00	11/01/2016 02:15:10	3	70
317	74.698220	21.466912	-88.00	50.00	11/01/2016 02:21:12	4	80
318	74.702581	21.471817	-86.00	40.00	11/01/2016 02:23:28	3	70
318	74.703739	21.471270	-85.00	45.00	11/01/2016 02:24:01	3	70
318	74.705277	21.475729	-87.00	40.00	11/01/2016 02:24:54	3	70
318	74.705757	21.471997	-86.00	50.00	11/01/2016 02:25:02	3	70
319	74.721105	21.487174	-99.00	50.00	11/01/2016 02:32:57	3	70
319	74.721113	21.489823	-101.00	55.00	11/01/2016 02:33:02	3	70
327	74.713121	21.469398	-86.00	55.00	11/01/2016 05:03:27	3	50
328	74.697757	21.456260	-88.00	45.00	11/01/2016 05:11:19	3	70
329	74.635202	21.403291	-126.00	60.00	11/01/2016 05:43:22	2	60
329	74.633048	21.400390	-126.00	60.00	11/01/2016 05:44:30	2	60

333	74.709484	21.456995	-84.00	50.00	11/01/2016 06:28:18	3	70
333	74.709949	21.458776	-84.00	75.00	11/01/2016 06:28:36	3	70
334	74.715033	21.490221	-92.00	50.00	11/01/2016 06:40:54	3	70
334	74.713869	21.489320	-90.00	45.00	11/01/2016 06:41:29	3	70
334	74.713944	21.488108	-90.00	70.00	11/01/2016 06:41:29	3	70
335	74.699964	21.464737	-87.00	60.00	11/01/2016 07:00:28	3	70
335	74.705518	21.472549	-85.00	70.00	11/01/2016 07:03:26	3	70
336	74.707913	21.461095	-84.00	50.00	11/01/2016 07:20:15	3	70
336	74.694524	21.450472	-90.00	90.00	11/01/2016 07:27:07	4	70
337	74.704729	21.490206	-90.00	70.00	11/01/2016 07:41:33	4	70
339	74.765793	21.509735	-132.00	70.00	11/01/2016 08:14:41	3	70
340	74.821209	21.559072	-121.00	60.00	11/01/2016 08:43:08	3	70
340	74.825823	21.564608	-116.00	70.00	11/01/2016 08:45:35	3	70
340	74.848054	21.586786	-104.00	70.00	11/01/2016 08:57:05	3	70
344	74.739933	21.474409	-134.00	75.00	11/01/2016 09:59:53	3	70
345	74.703052	21.442805	-88.00	50.00	11/01/2016 10:18:51	3	70
345	74.689959	21.432872	-92.00	60.00	11/01/2016 10:25:32	3	60
365	74.790142	21.489269	-129.00	80.00	11/01/2016 16:15:47	4	70
367	74.845892	21.525641	-115.00	50.00	11/01/2016 16:56:22	3	70
367	74.840047	21.520522	-109.00	40.00	11/01/2016 16:59:22	3	60
368	74.797206	21.484629	-123.00	65.00	11/01/2016 17:21:18	3	70
369	74.775263	21.465181	-123.00	60.00	11/01/2016 17:32:33	3	70
376	74.779063	21.457743	-126.00	40.00	11/01/2016 20:04:54	2	60
400	74.753423	21.391595	-121.00	60.00	11/02/2016 03:42:54	3	70
402	74.844111	21.467507	-108.00	40.00	11/02/2016 04:29:19	3	60
416	74.743838	21.362653	-106.00	50.00	11/02/2016 08:02:16	2	60
418	74.816171	21.422899	-113.00	40.00	11/02/2016 08:39:19	2	60
418	74.844603	21.447029	-112.00	45.00	11/02/2016 08:53:53	2	60
423	74.741544	21.351579	-103.00	90.00	11/02/2016 10:05:16	4	70

444	74.831391	21.392215	-102.00	70.00	11/02/2016 16:41:26	3	70
444	74.854226	21.409264	-101.00	65.00	11/02/2016 16:53:05	4	70
473	74.855749	21.357812	-93.00	60.00	11/03/2016 01:20:01	2	60
487	74.849449	21.380128	-96.00	50.00	11/03/2016 05:37:03	2	60
490	74.811665	21.304067	-108.00	60.00	11/03/2016 06:16:19	2	60
511	74.849624	21.305950	-97.00	40.00	11/03/2016 13:44:45	3	60
512	74.851897	21.297396	-93.00	50.00	11/03/2016 14:07:09	3	60
513	74.796189	21.251447	-103.00	50.00	11/03/2016 14:35:39	3	70
528	74.645491	21.114047	-95.00	30.00	11/03/2016 19:52:22	3	70
540	74.644264	21.143962	-98.00	25.00	11/04/2016 00:01:35	2	60
555	74.856384	21.243629	-87.00	20.00	11/04/2016 02:48:10	2	40
566	74.787305	21.158337	-101.00	53.00	11/04/2016 06:32:37	3	70
567	74.836283	21.197511	-89.00	23.00	11/04/2016 06:57:33	3	70
567	74.848512	21.210281	-86.00	40.00	11/04/2016 07:03:49	3	70
570	74.834723	21.183559	-97.00	30.00	11/04/2016 08:04:33	2	50
576	74.860209	21.197402	-81.00	52.00	11/04/2016 09:06:42	2	50
578	74.844034	21.225705	-88.00	46.00	11/04/2016 09:24:37	3	60
579	74.838124	21.381797	-100.00	80.00	11/04/2016 09:45:07	3	70
579	74.835846	21.435417	-109.00	59.00	11/04/2016 09:52:13	2	50
579	74.832751	21.508440	-115.00	66.00	11/04/2016 10:01:50	3	60
597	74.779108	21.917818	-147.00	55.00	11/04/2016 17:07:54	3	60
611	74.753942	21.790085	-147.00	45.00	11/04/2016 21:59:38	2	50
614	74.635344	21.685875	-155.00	35.00	11/04/2016 22:59:12	3	60
617	74.717646	21.710559	-144.00	22.00	11/05/2016 00:19:53	3	60
623	74.731175	21.710722	-147.00	96.00	11/05/2016 02:24:15	4	70
628	74.707410	21.663447	-145.00	76.00	11/05/2016 04:05:06	3	70
630	74.770230	21.720701	-135.00	80.00	11/05/2016 04:36:41	3	60
631	74.852284	21.794902	-115.00	70.00	11/05/2016 05:17:56	2	50

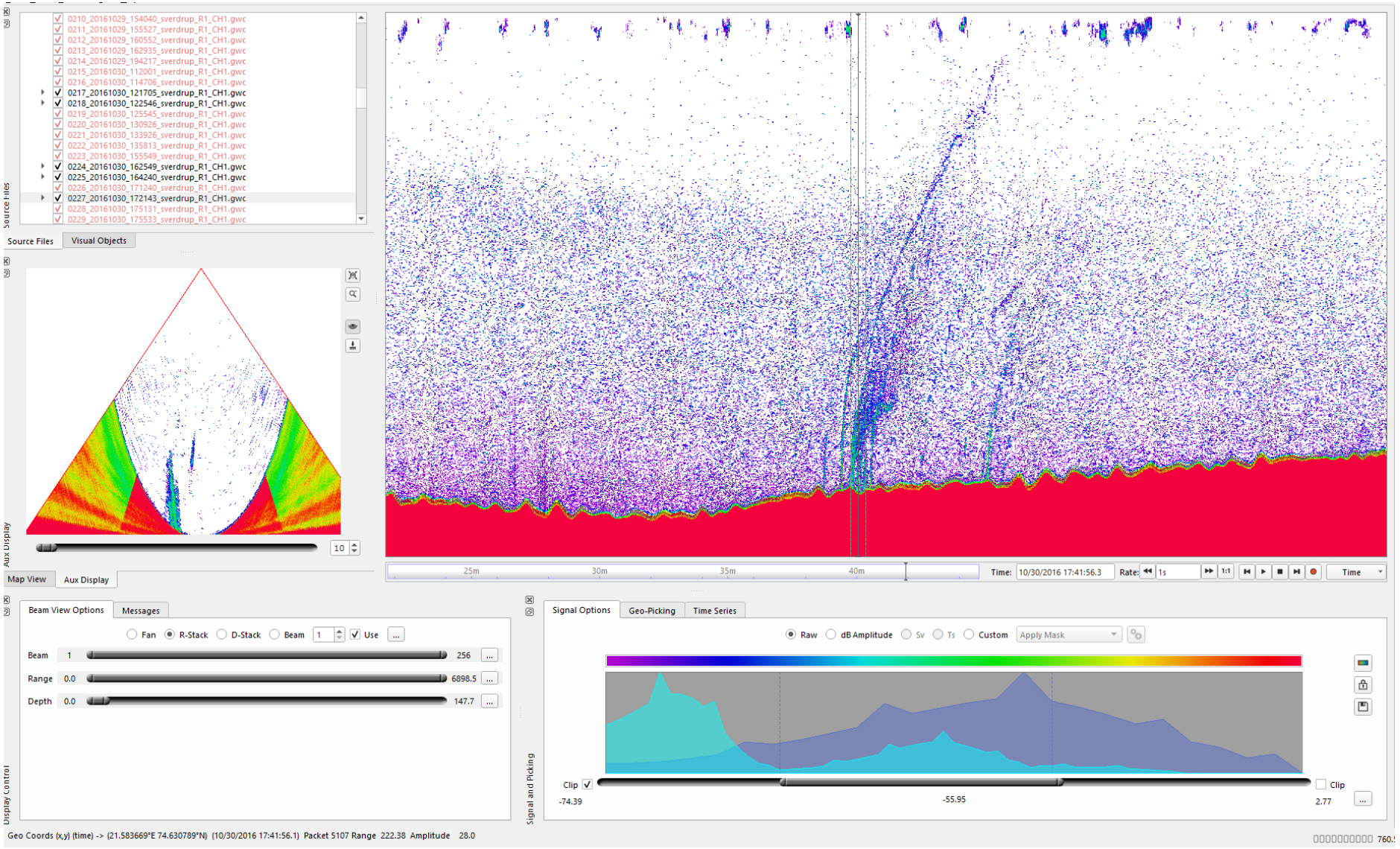


Figure 17. Gas flare from line 227, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

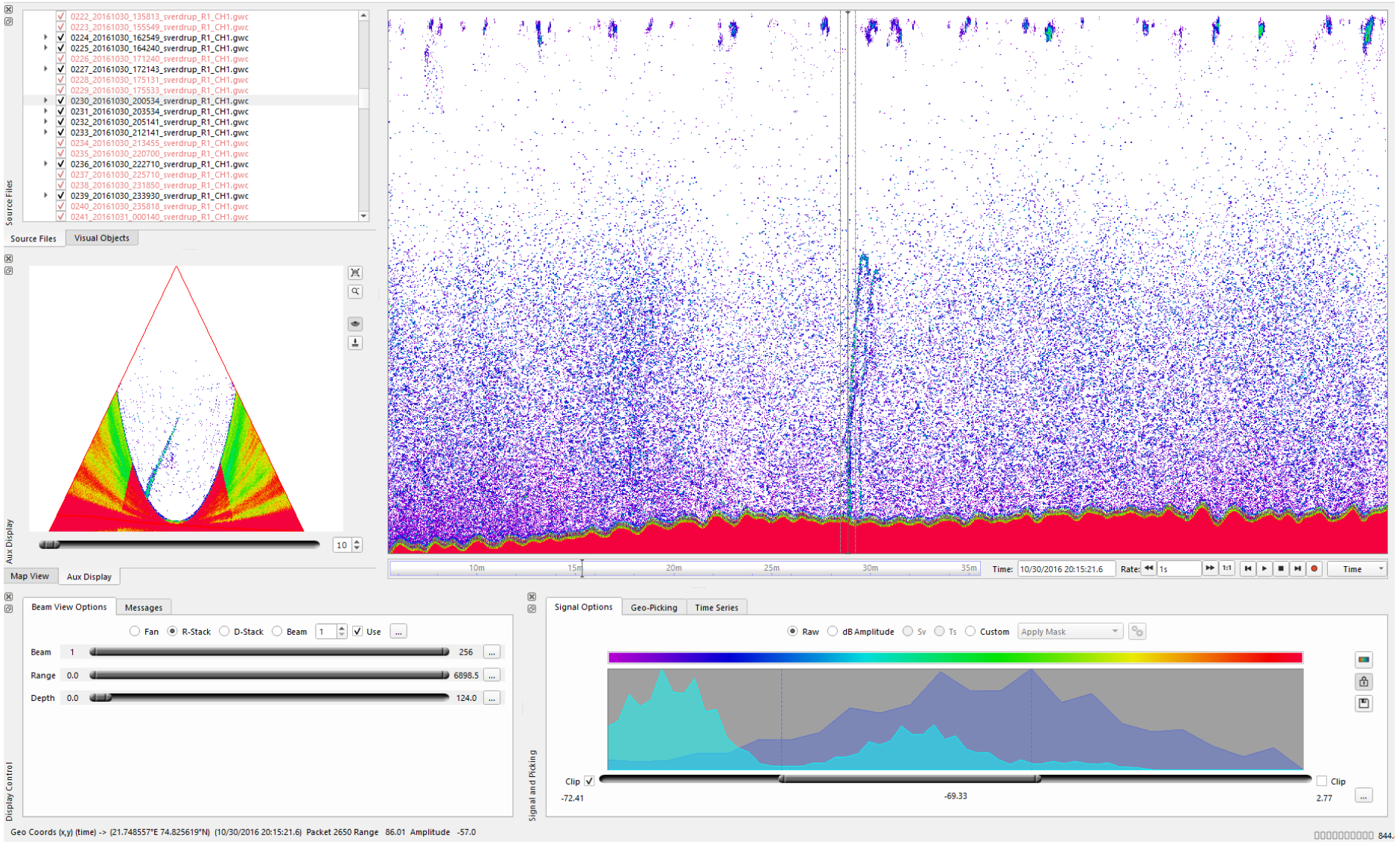


Figure 18. Gas flare from line 230, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

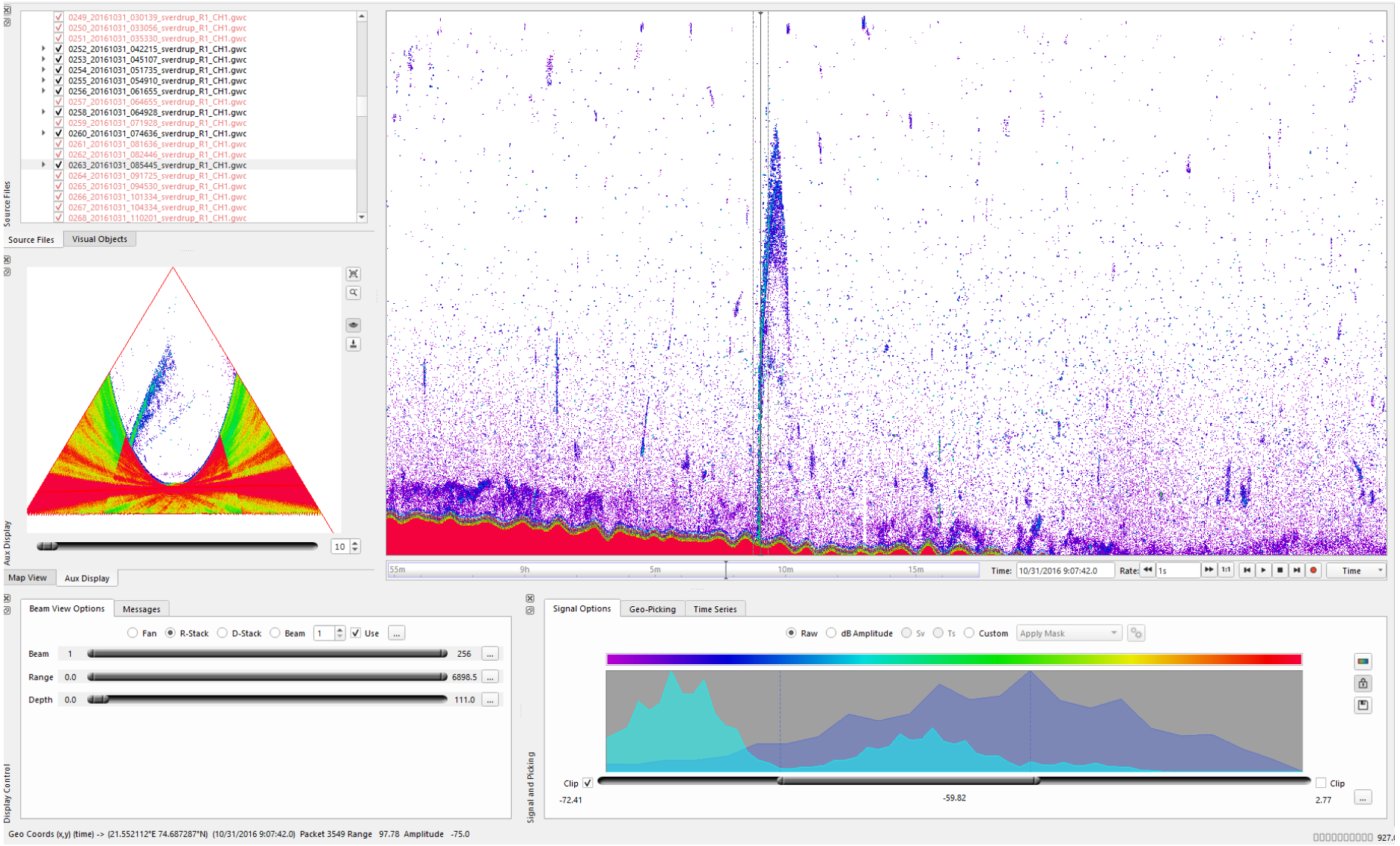


Figure 19. Gas flare from line 263, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

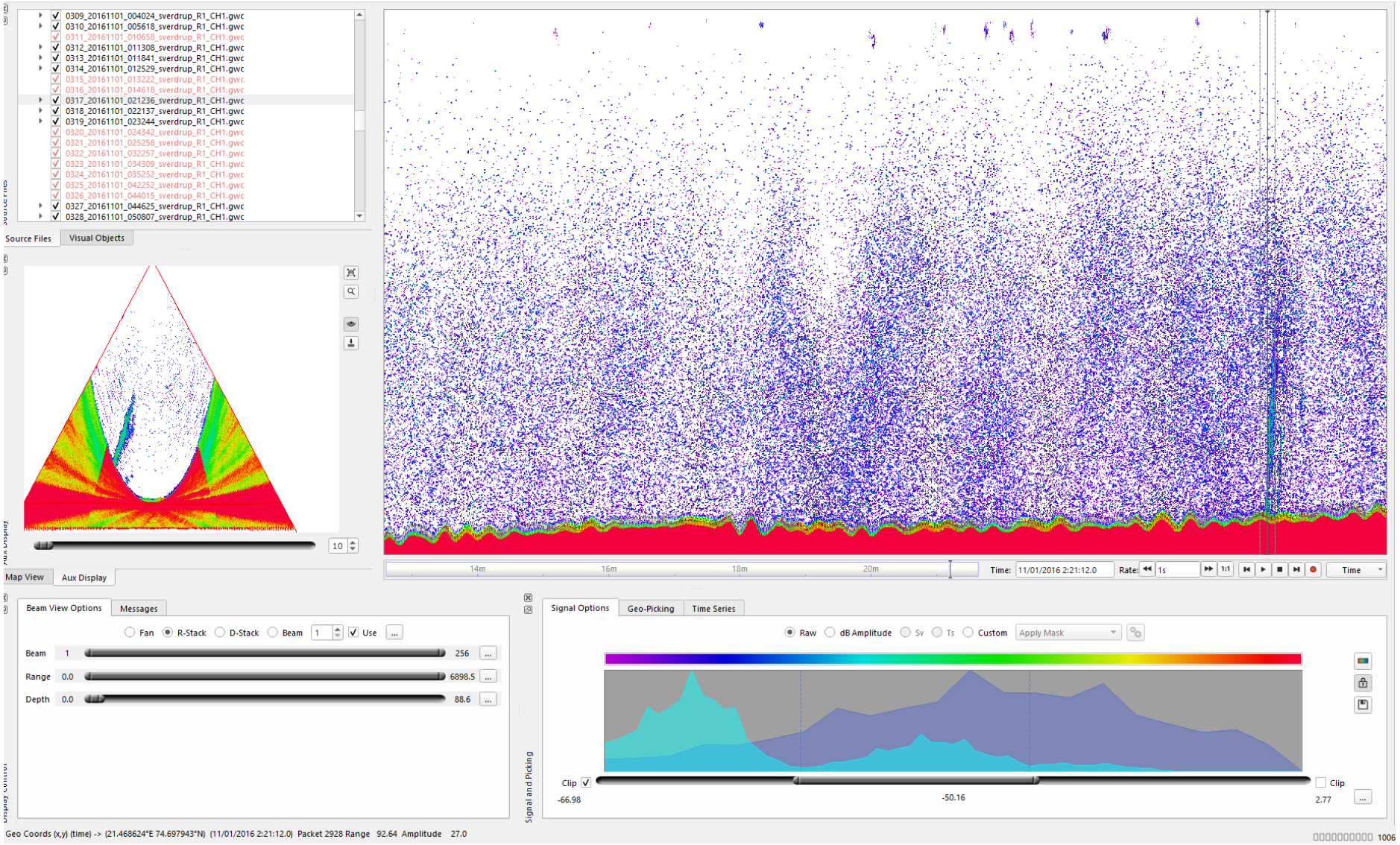


Figure 20. Gas flare from line 317, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

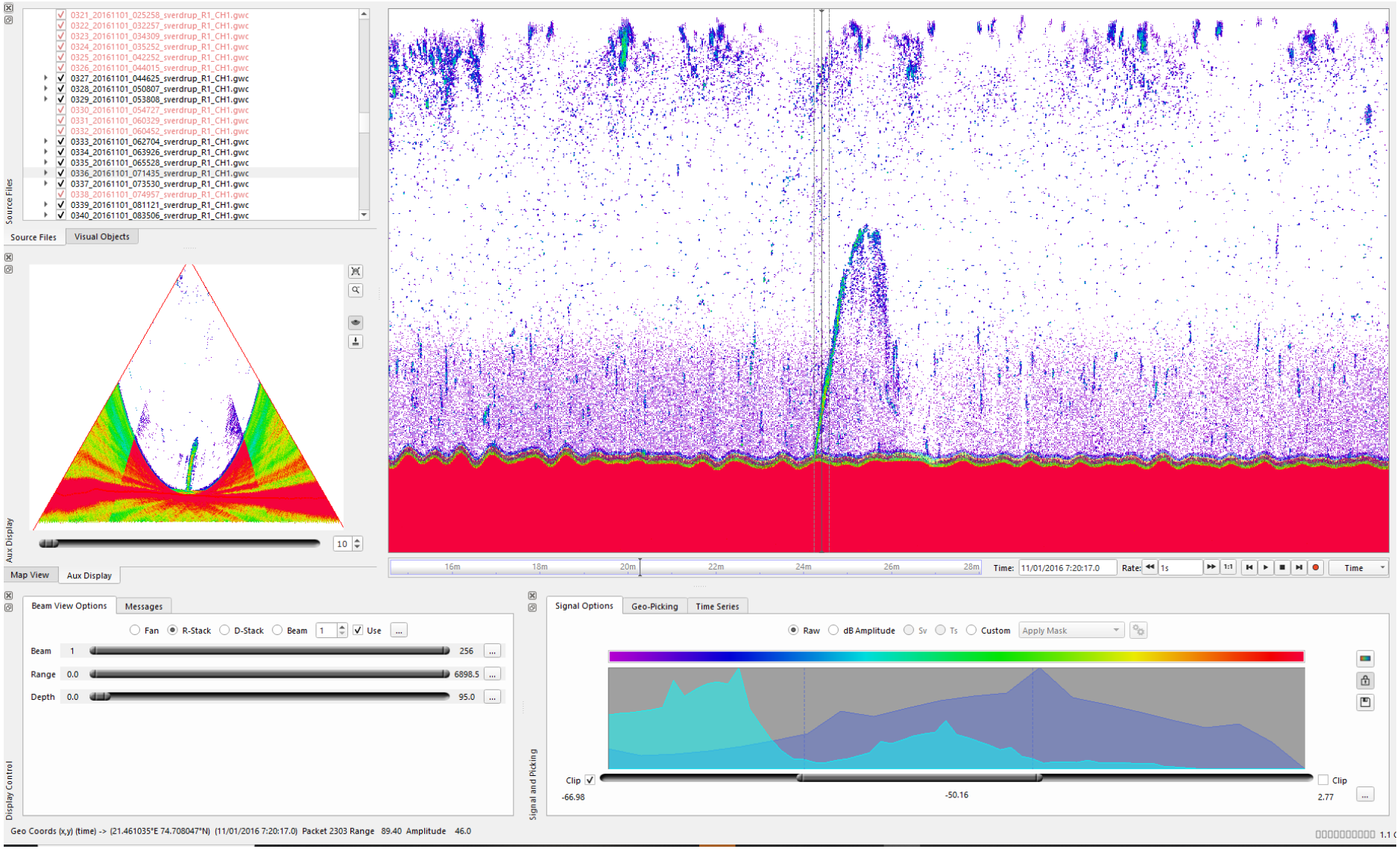


Figure 21. Gas flare from line 336, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

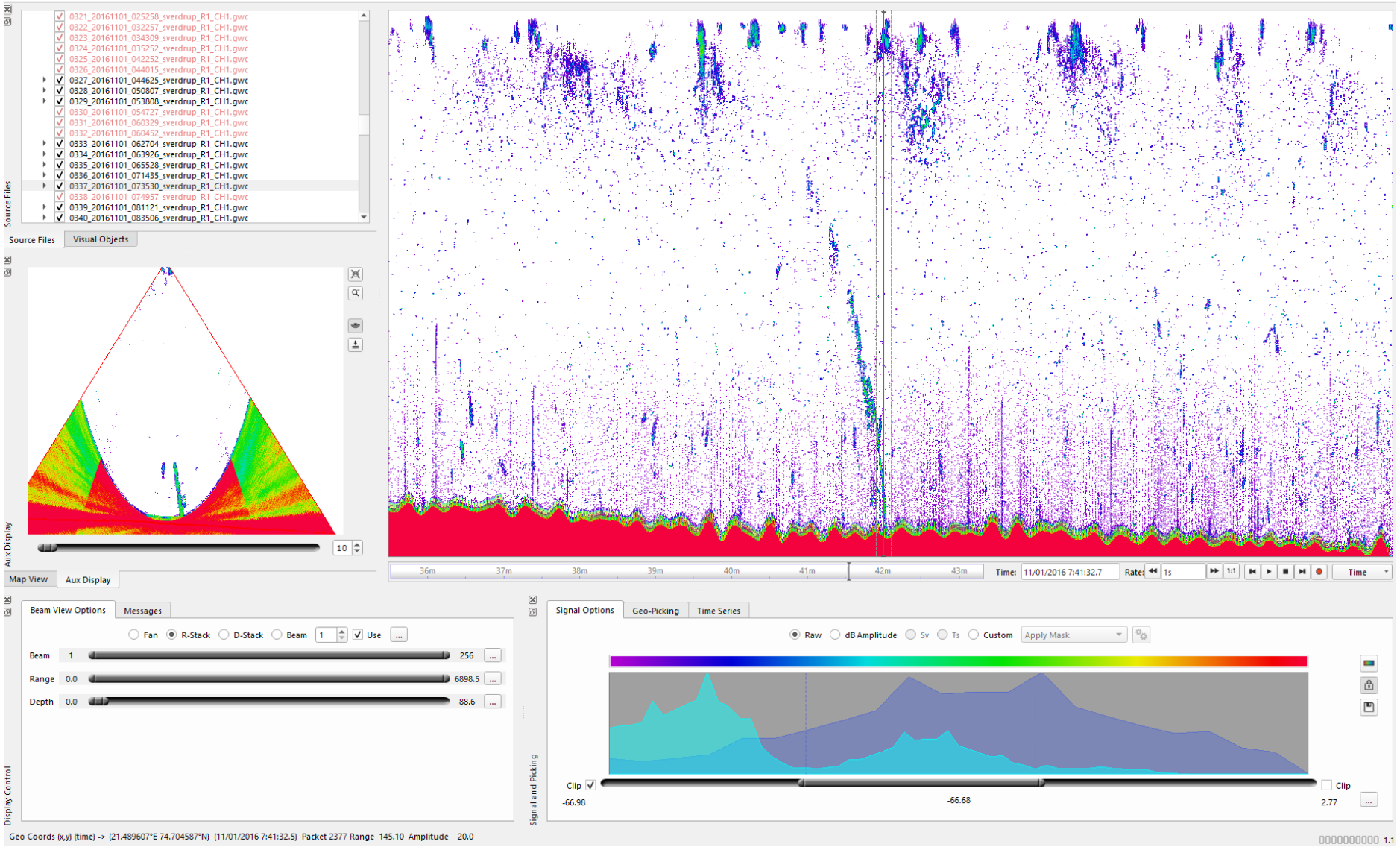


Figure 22. Gas flare from line 337, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

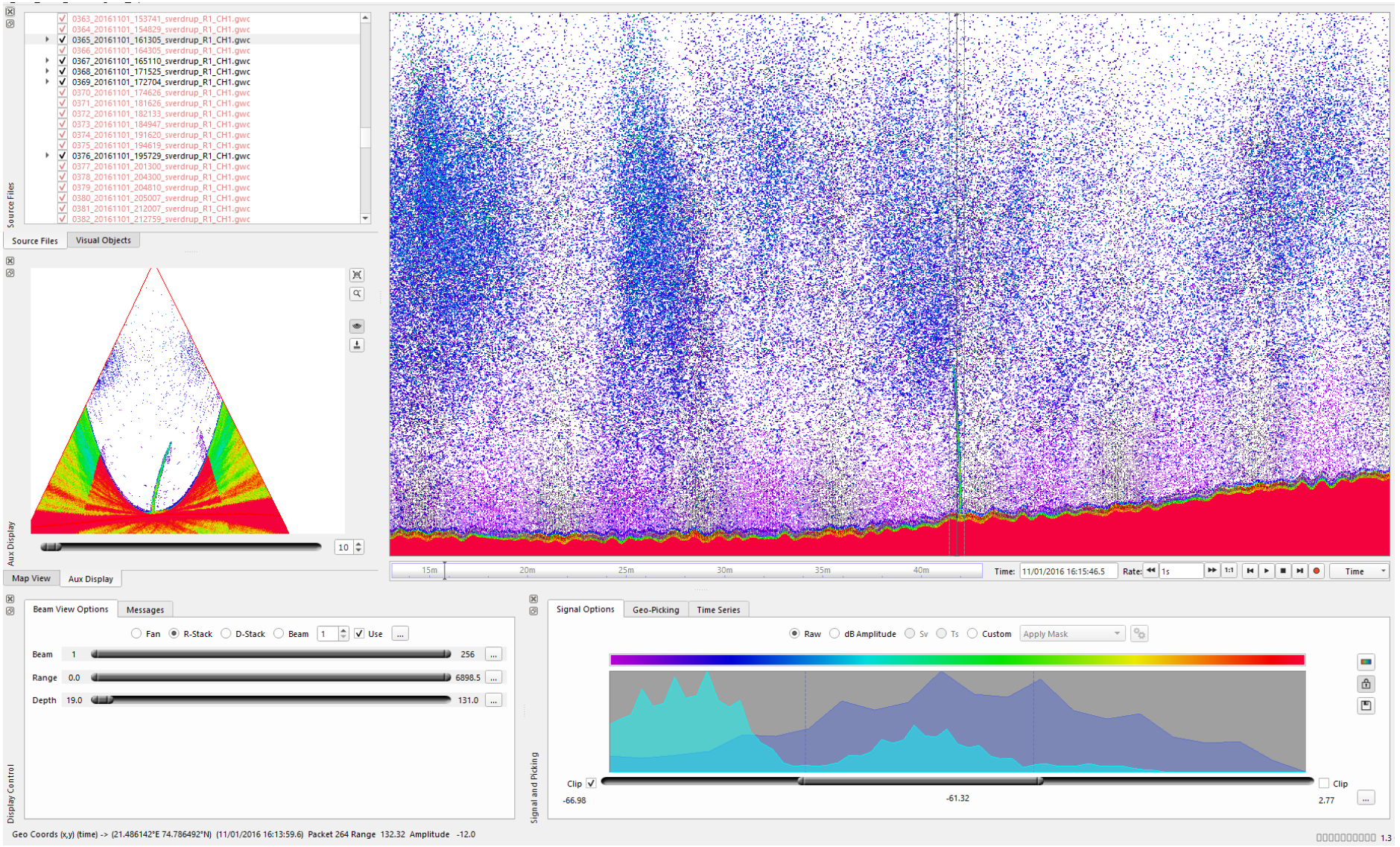


Figure 23. Gas flare from line 365, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

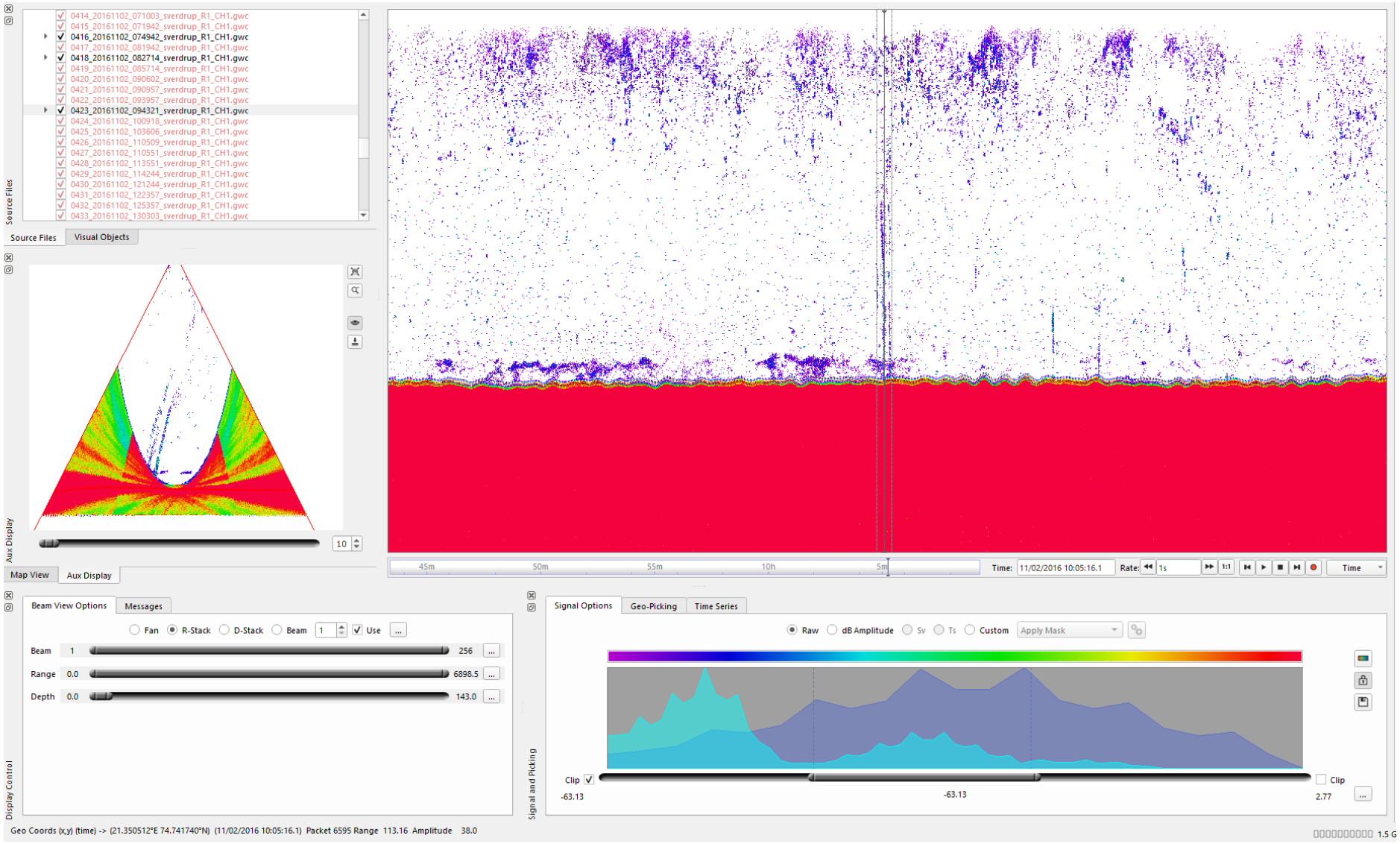


Figure 24. Gas flare from line 423, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

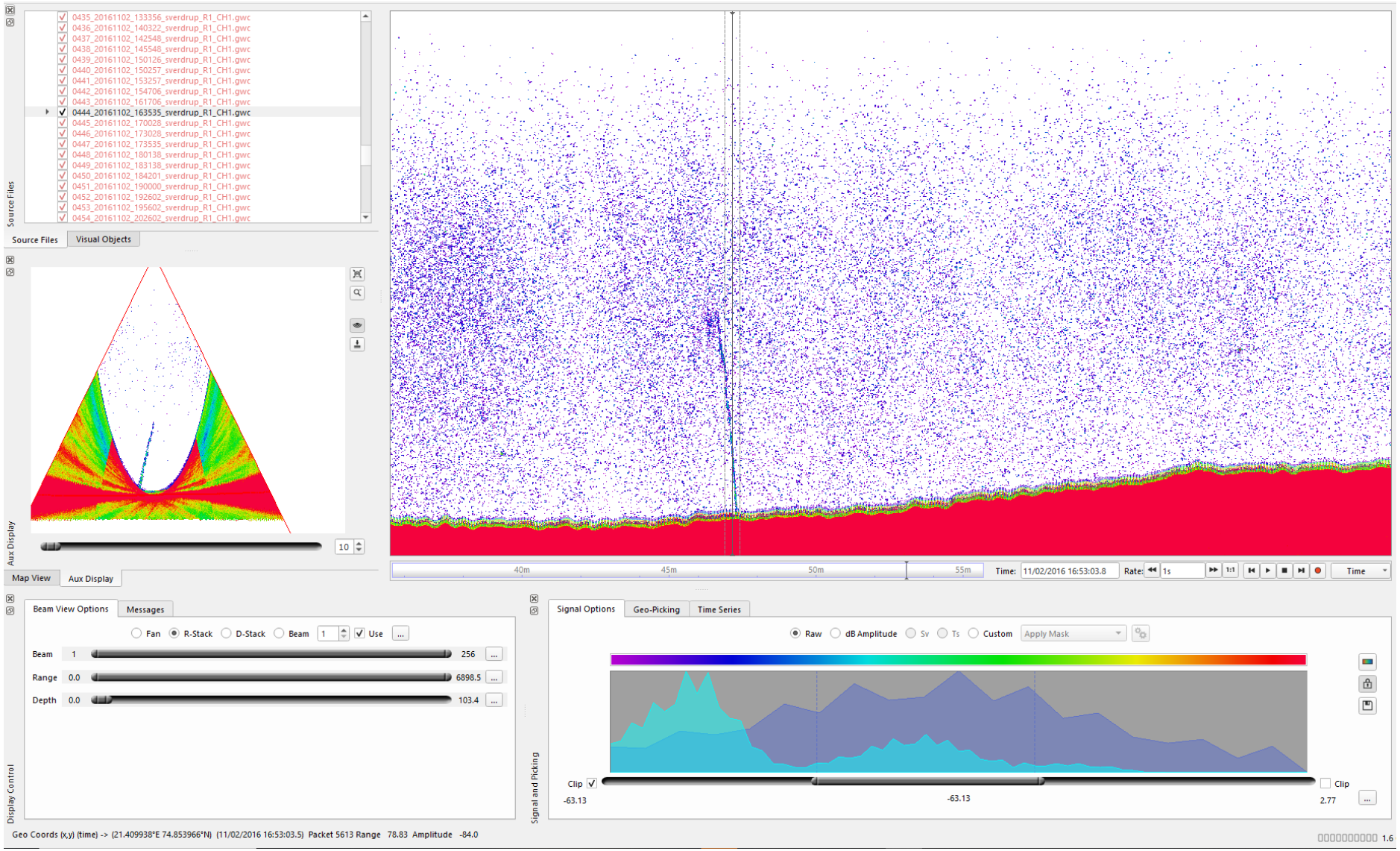


Figure 25. Gas flare from line 444, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

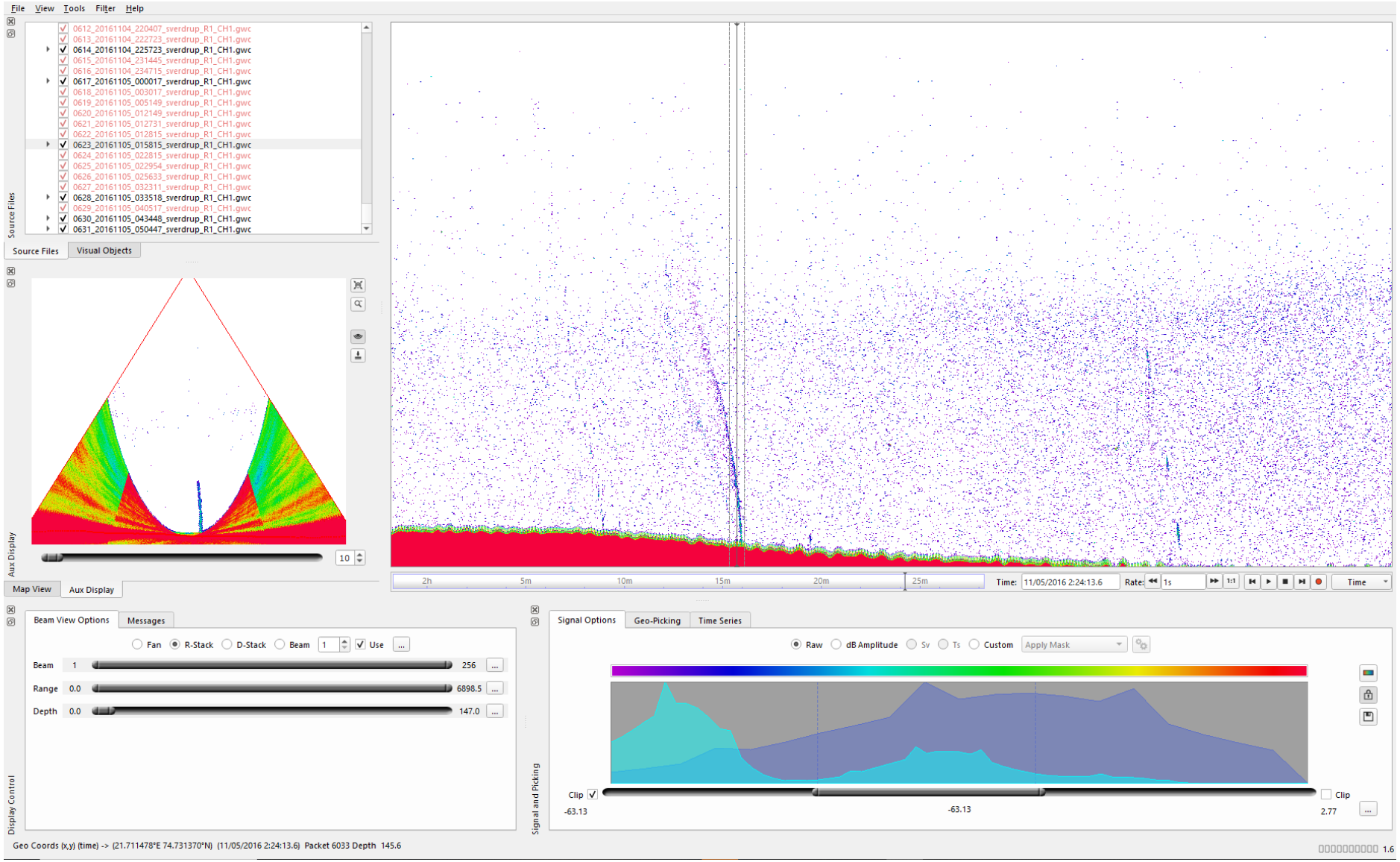


Figure 26. Gas flare from line 623, Sverdrup-2016-009 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

4.1.10 Sverdrup-2016-010

The Sverdrup-2016-010 survey consists of 292 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 5 flares were found in the data (Table 7). One flare of sizes 4 is shown on in Fig. 27.

Table 7. Details of flares identified from Survey Area Sverdrup-2016-010.

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
142	72.687171	25.268754	-277.00	140.00	02/28/2016 8:07:26.7	4	80
157	72.661569	25.288012	-263.00	130.00	02/28/2016 12:49:42.0	3	50
158	72.660500	25.307177	-262.00	180.00	02/28/2016 13:01:12.	3	70
158	72.662095	25.308486	-263.00	120.00	02/28/2016 13:02:07.1	3	70
172	72.663359	25.327982	-259.00	140.00	02/28/2016 17:23:59.8	3	70

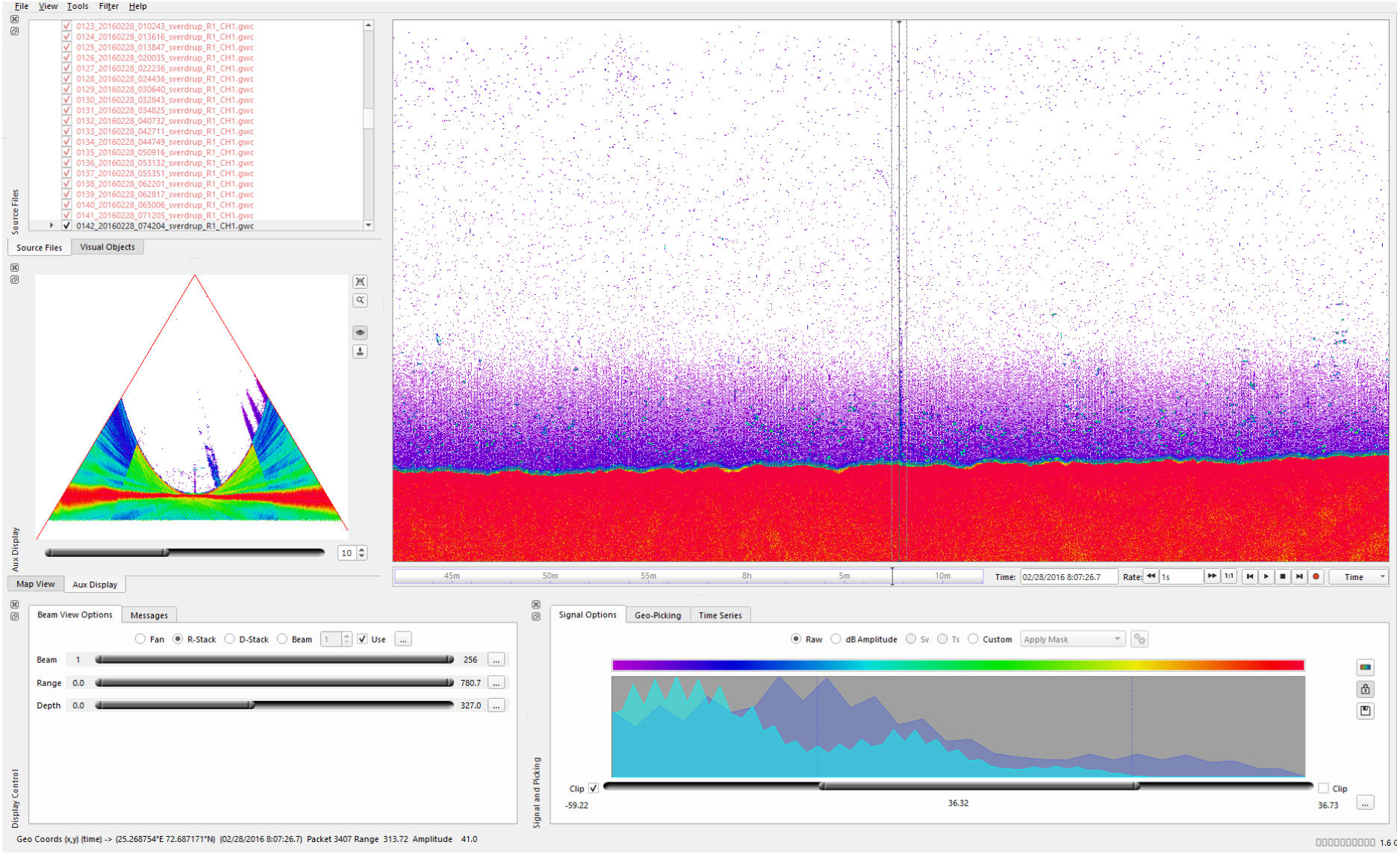


Figure 27. Gas flare from line 142, Sverdrup-2016-010 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

4.1.11 Sverdrup-2016-011

The Sverdrup-2016-011 survey consists of 293 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. No flares were found in the data.

4.1.12 Sverdrup-2016-012

The Sverdrup-2016-012 survey consists of 402 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 9 flares were found in the data (Table 8). One flare of sizes 4 is shown on in Figs. 28.

Table 8. Details of flares identified from Survey Area Sverdrup-2016-012.

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
9	74.455339	22.434801	-104.00	100.00	04/21/2016 18:51:56.4	4	70
21	74.427716	22.408225	-109.00	80.00	04/22/2016 1:00:47.5	3	60
22	74.470794	22.430011	-108.00	40.00	04/22/2016 1:30:43.2	3	50
30	74.371188	22.372363	-124.00	60.00	04/22/2016 6:07:26.3	3	70
30	74.371425	22.373193	-125.00	60.00	04/22/2016 6:07:38.4	3	70
56	74.475723	22.406999	-102.00	50.00	04/22/2016 19:52:55.4	3	60
113	74.448993	22.345986	-102.00	50.00	04/23/2016 11:34:01.8	3	70
118	74.448973	22.346037	-102.00	62.00	04/23/2016 12:58:45.5	3	70
265	74.421795	22.078104	-171.00	110.00	04/25/2016 1:04:56.7	3	70

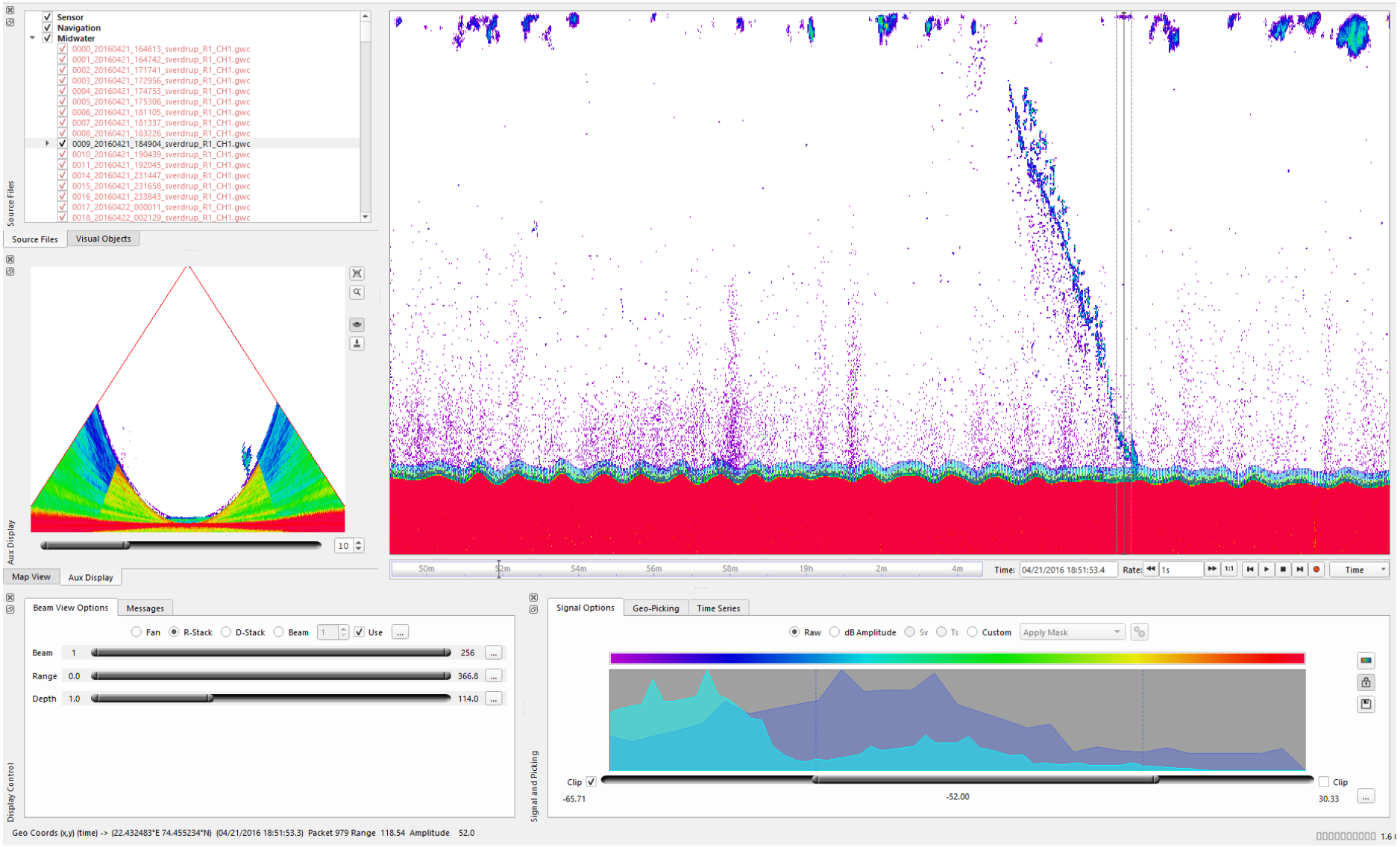


Figure 28. Gas flare from line 9, Sverdrup-2016-012 showed on Fan view and stack view. Magnitude 4, Confidence 70%.

4.1.13 Sverdrup-2016-014

The Sverdrup-2016-014 survey consists of 377 water column (*.wcd) survey lines. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 9 flares were found in the data (Table 9). Three flares of sizes 4 are shown on in Figs. 29 -31.

Table 9. Details of flares identified from Survey Area Sverdrup-2016-014.

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
140	74.392069	21.729409	-206.00	80.00	04/28/2016 21:27:14.9	3	70
169	74.505873	21.738035	-203.00	90.00	04/29/2016 4:39:13.3	3	70
180	74.302767	21.628320	-201.00	60.00	04/29/2016 7:06:46.7	3	70
296	74.538706	21.602602	-165.00	100.00	04/30/2016 7:54:10.4	3	60
317	74.327116	21.509942	-155.00	75.00	04/30/2016 11:56:53.9	4	80
330	74.524761	21.585619	-157.00	120.00	04/30/2016 15:09:29.3	3	70
330	74.525668	21.585855	-157.00	100.00	04/30/2016 15:10:03.0	4	80
330	74.529941	21.589066	-154.00	100.00	04/30/2016 15:12:42.5	3	60
332	74.512897	21.568501	-159.00	100.00	04/30/2016 15:44:26.7	4	80

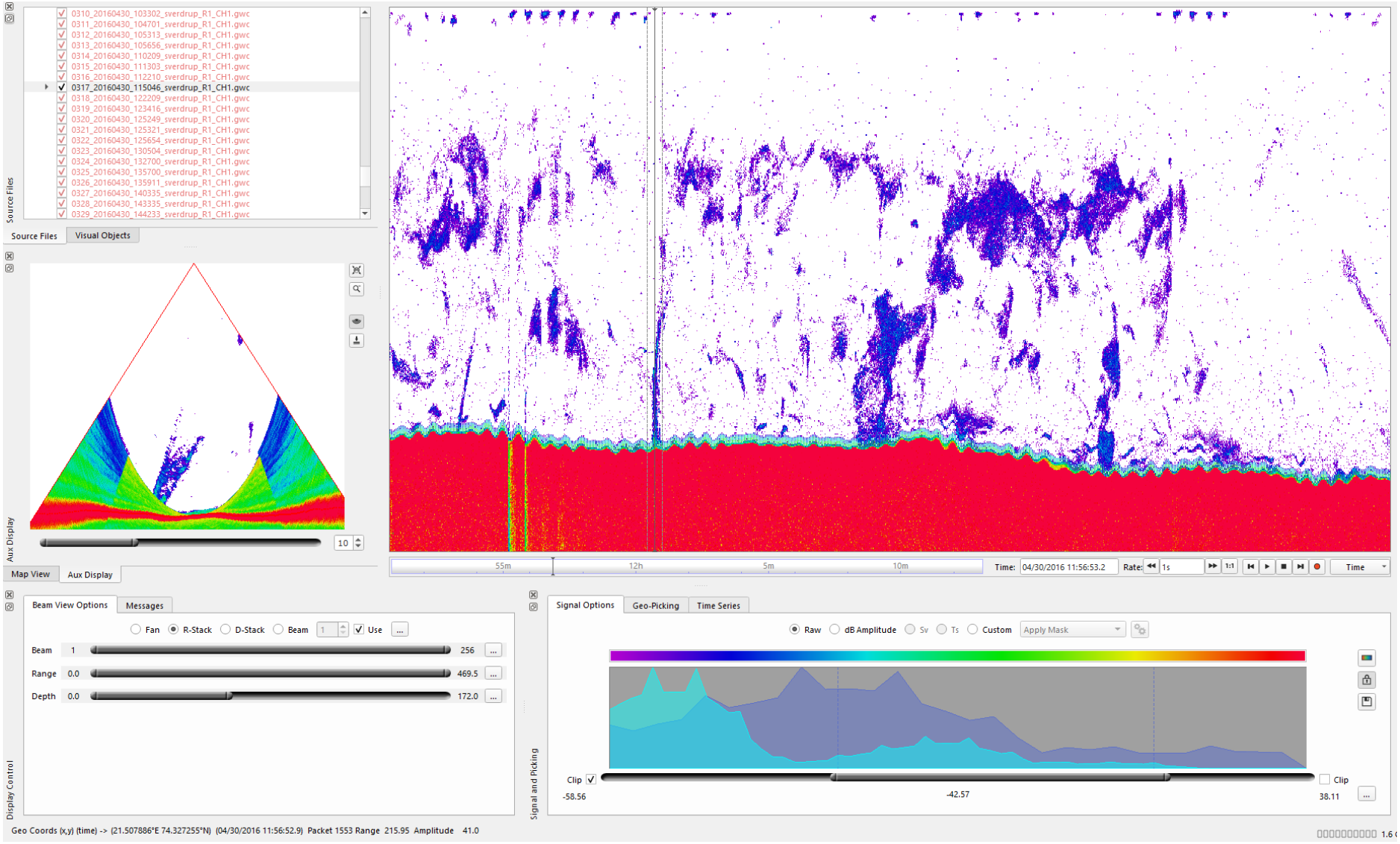


Figure 29. Gas flare from line 317, Sverdrup-2016-014 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

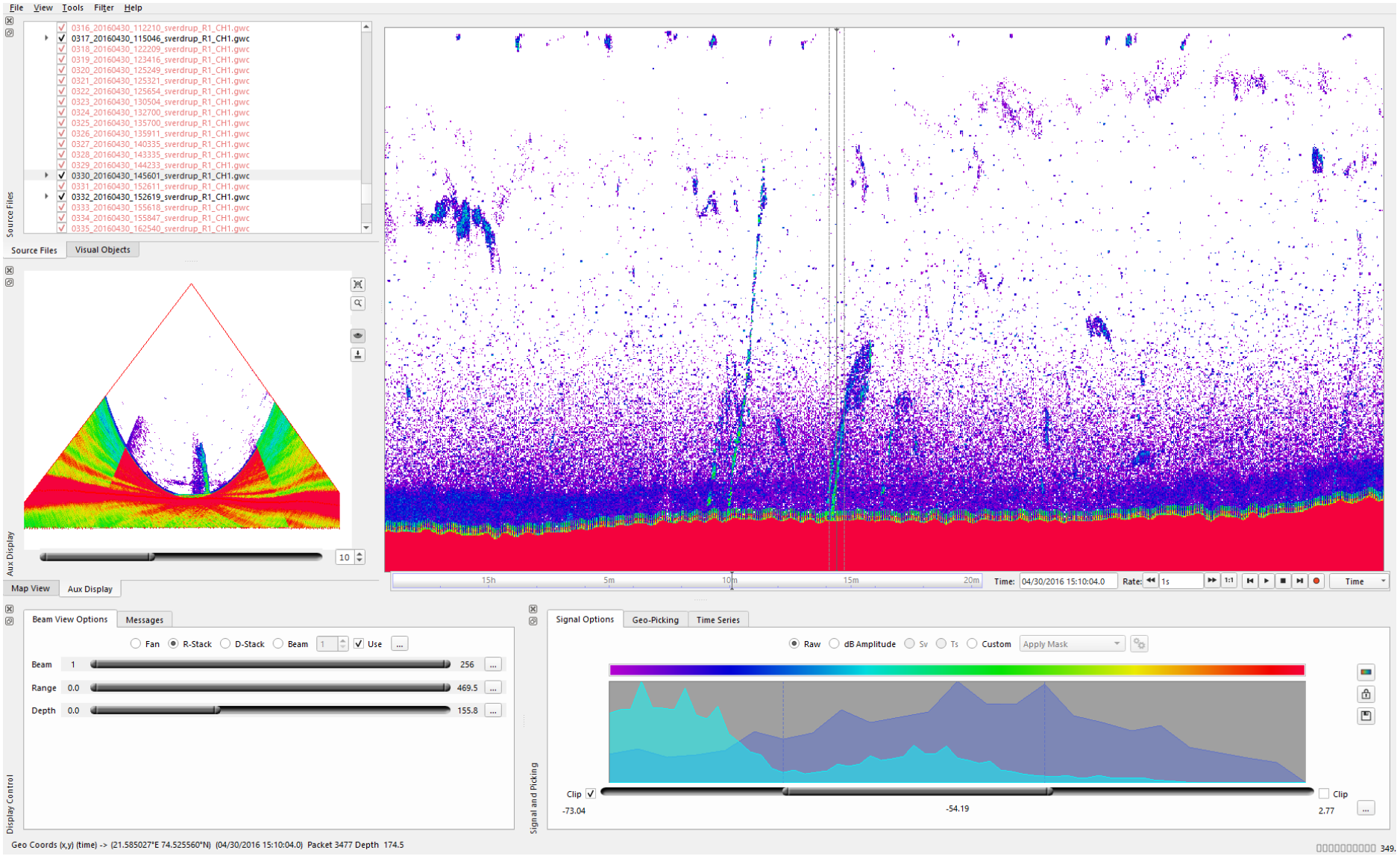


Figure 30. Gas flare from line 330, Sverdrup-2016-014 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

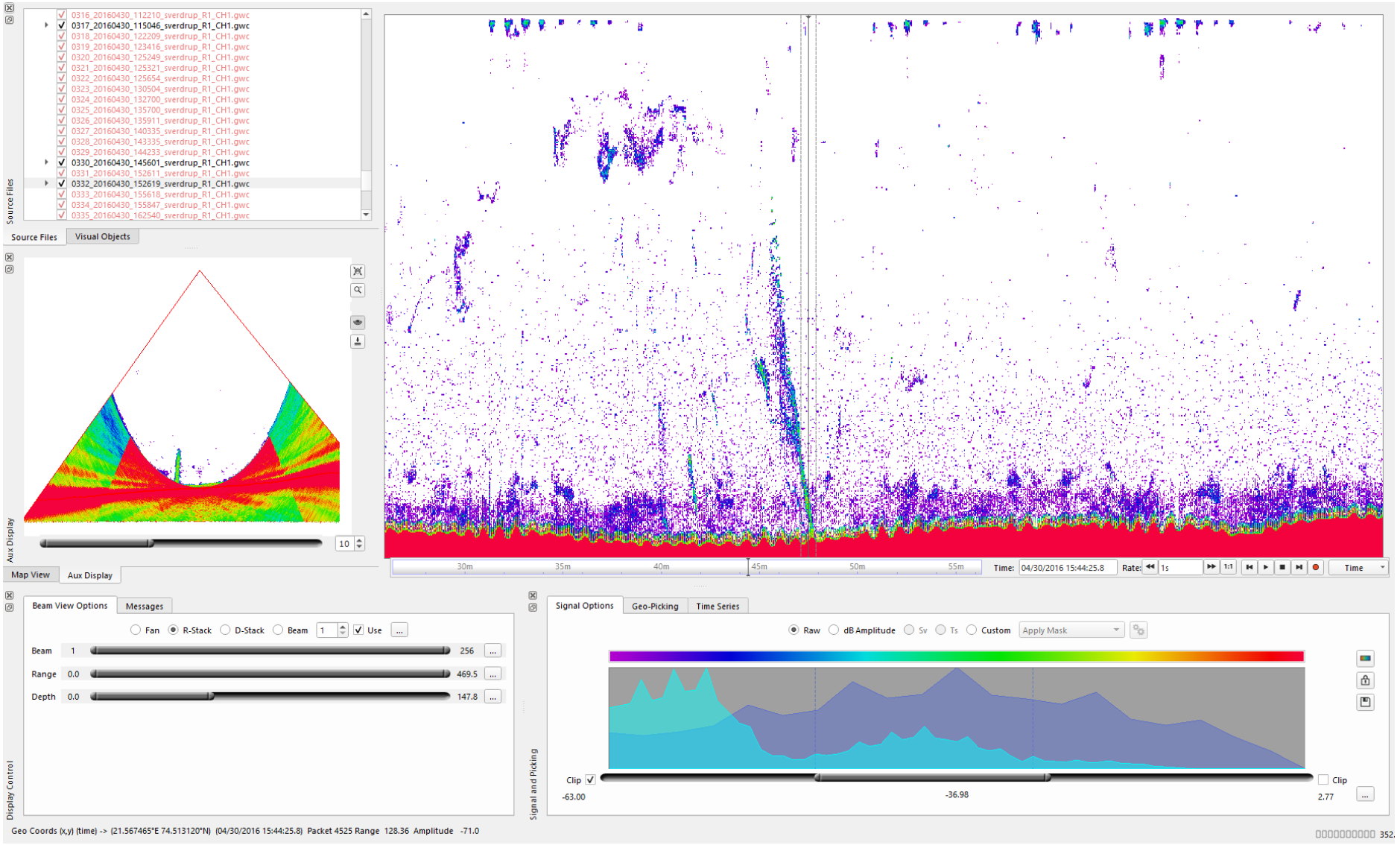


Figure 31. Gas flare from line 332, Sverdrup-2016-014 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

4.1.14 Fgmg-2020-TR-NS02-NS03

The fgmg-2020-TR-NS02-NS03 survey consists of 230 water column (*.wcd) survey lines divided in c1 to c4 cells. The data was loaded in Fledermaus Midwater along with navigation (*.all) and converted to GWC files and analysed visually. The data have a lot of weather-related noise and therefore interpretation to identify occurrences was difficult. 26 flares were found in the data (Table 10). Four flares of sizes 4 are shown on in Figs. 32 - 36.

Table 10. Details of flares identified from Survey Area fgmg-2020-TR-NS02-NS03.

LineId	Latitude	Longitude	Depth	Height	Time	Magnitude	Confidence
3477	74.236862	21.798799	-264.00	80.00	09/07/2020 21:12:22	3	60
3484	74.226482	21.870358	-275.00	80.00	09/07/2020 23:25:34	2	30
3484	74.225496	21.917911	-285.00	80.00	09/07/2020 23:19:49	3	60
3485	74.230598	21.762006	-253.00	120.00	09/07/2020 23:38:43	3	70
3267	74.201197	22.050243	-270.00	110.00	09/04/2020 18:44:43	3	70
3267	74.201287	22.038703	-277.00	75.00	09/04/2020 18:43:23	3	70
3268	74.205026	22.084658	-248.00	210.00	09/04/2020 18:49:15	5	90
3273	74.174746	22.158823	-275.00	40.00	09/04/2020 20:36:39	2	30
3273	74.160721	22.171997	-293.00	80.00	09/04/2020 20:30:27	3	40
3275	74.193120	22.076699	-262.00	70.00	09/04/2020 21:31:52	3	70
3275	74.192780	22.078175	-277.00	70.00	09/04/2020 21:32:05.0	3	70
3275	74.191737	22.07904	-281.00	80.00	09/04/2020 21:32:29.2	3	70
3275	74.191272	22.078598	-280.00	90.00	09/04/2020 21:32:36.7	3	70
3276	74.188091	22.084143	-270.00	180.00	09/04/2020 21:34:01	3	80
3276	74.182217	22.111350	-275.00	170.00	09/04/2020 21:37:44	3	80
3276	74.183346	22.103205	-276.00	130.00	09/04/2020 21:36:50	3	80
3276	74.158493	22.170196	-298.00	220.00	09/04/2020 21:49:08	4	80
3279	74.182865	22.07377	-293.00	110.00	09/04/2020 22:42:49.9	3	80
3279	74.182944	22.073420	-274.00	135.00	09/04/2020 22:42:54	3	80
3279	74.183626	22.074442	-290.00	106.00	09/04/2020 22:43:12.9	3	80
3279	74.183914	22.074746	-271.00	110.00	09/04/2020 22:43:21	3	80

3279	74.184123	22.070413	-271.00	110.00	09/04/2020 22:43:54	4	80
3279	74.184511	22.071767	-289.00	110.00	09/04/2020 22:43:59.8	3	80
3279	74.185441	22.070423	-269.00	120.00	09/04/2020 22:44:41	3	80
3280	74.190968	22.058513	-273.00	100.00	09/04/2020 22:49:13	3	70
3283	74.185003	22.045647	-272.00	110.00	09/04/2020 23:49:21	3	80
3283	74.181720	22.040279	-278.00	190.00	09/04/2020 23:50:10	3	60
3283	74.180251	22.044185	-282.00	150.00	09/04/2020 23:50:56	3	40
3286	74.175537	22.038341	-273.00	80.00	09/05/2020 00:49:11	3	60
3286	74.177873	22.032756	-275.00	160.00	09/05/2020 00:50:16	5	90
3289	74.182867	21.994910	-284.00	80.00	09/05/2020 01:45:36	3	60
3307	74.160817	21.894009	-304.00	180.00	09/05/2020 07:59:46	3	70

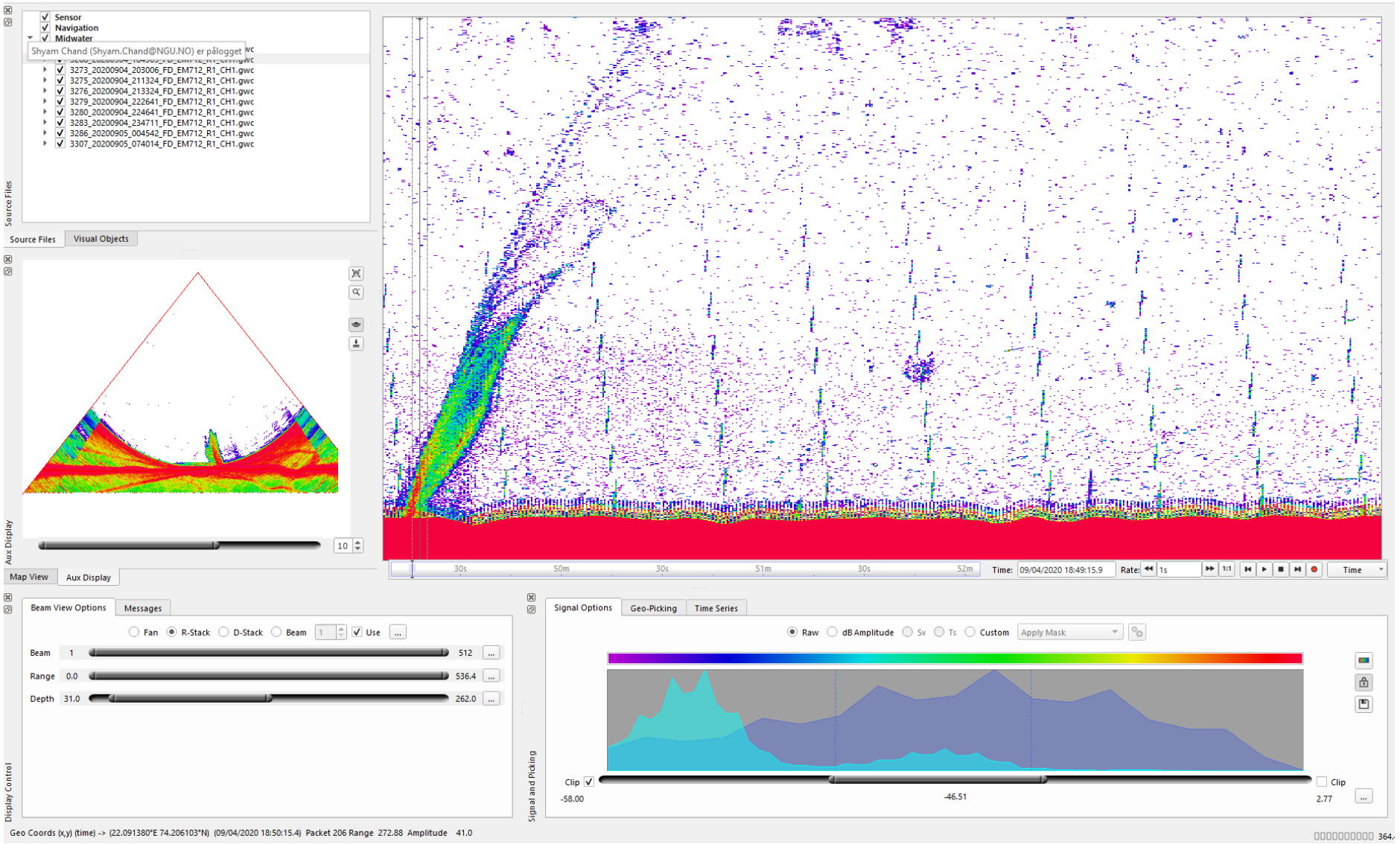


Figure 33. Gas flare from line 3268, fgmg-2020-TR-NS02-NS03-c2 showed on Fan view and stack view. Magnitude 5, Confidence 90%.

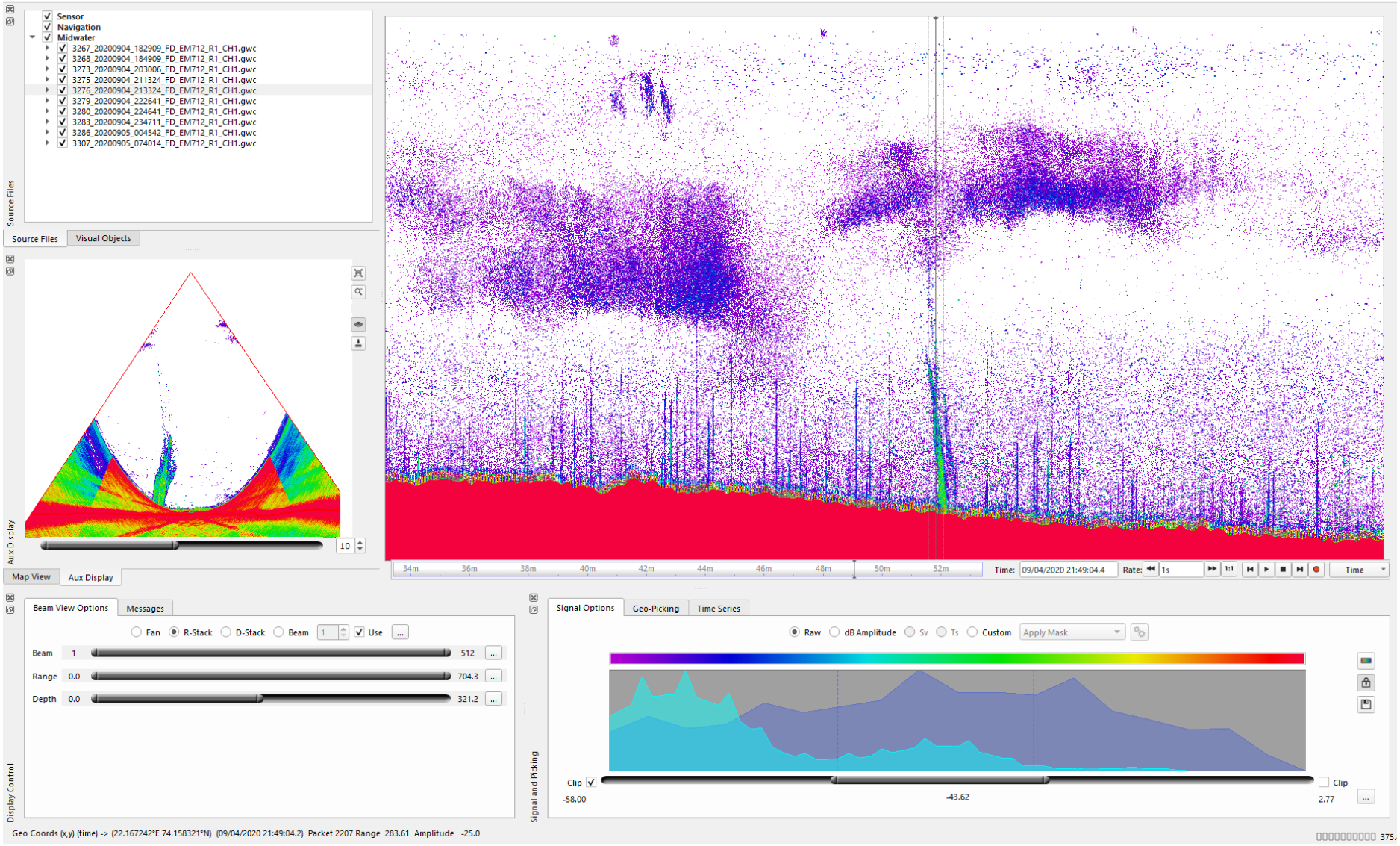


Figure 34. Gas flare from line 3276, fgmg-2020-TR-NS02-NS03-c2 showed on Fan view and stack view. Magnitude 4, Confidence 80%.

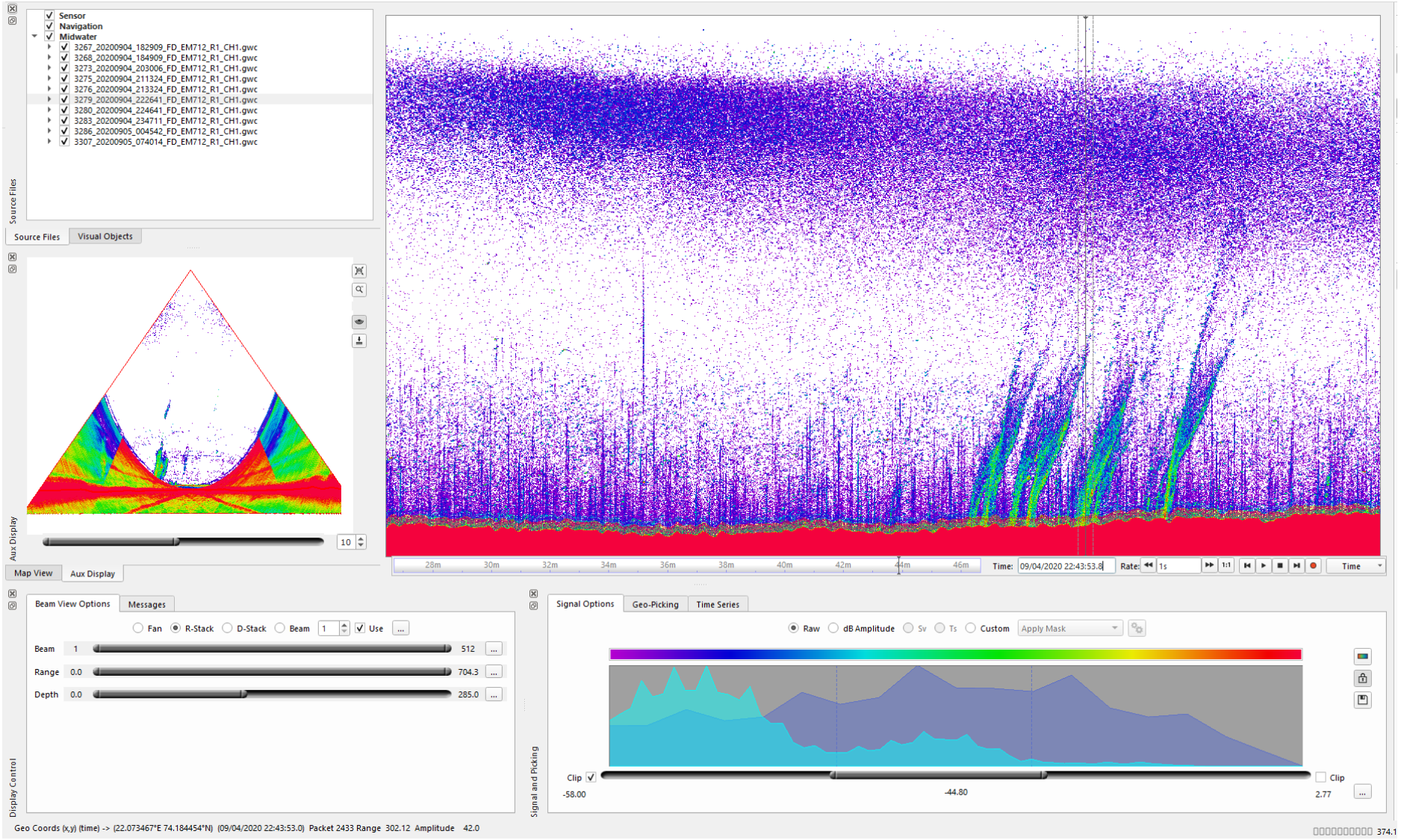


Figure 35. Gas flares from line 3279, fgmg-2020-TR-NS02-NS03-c2 showed on Fan view and stack view. Magnitude 3 & 4, Confidence 80%.

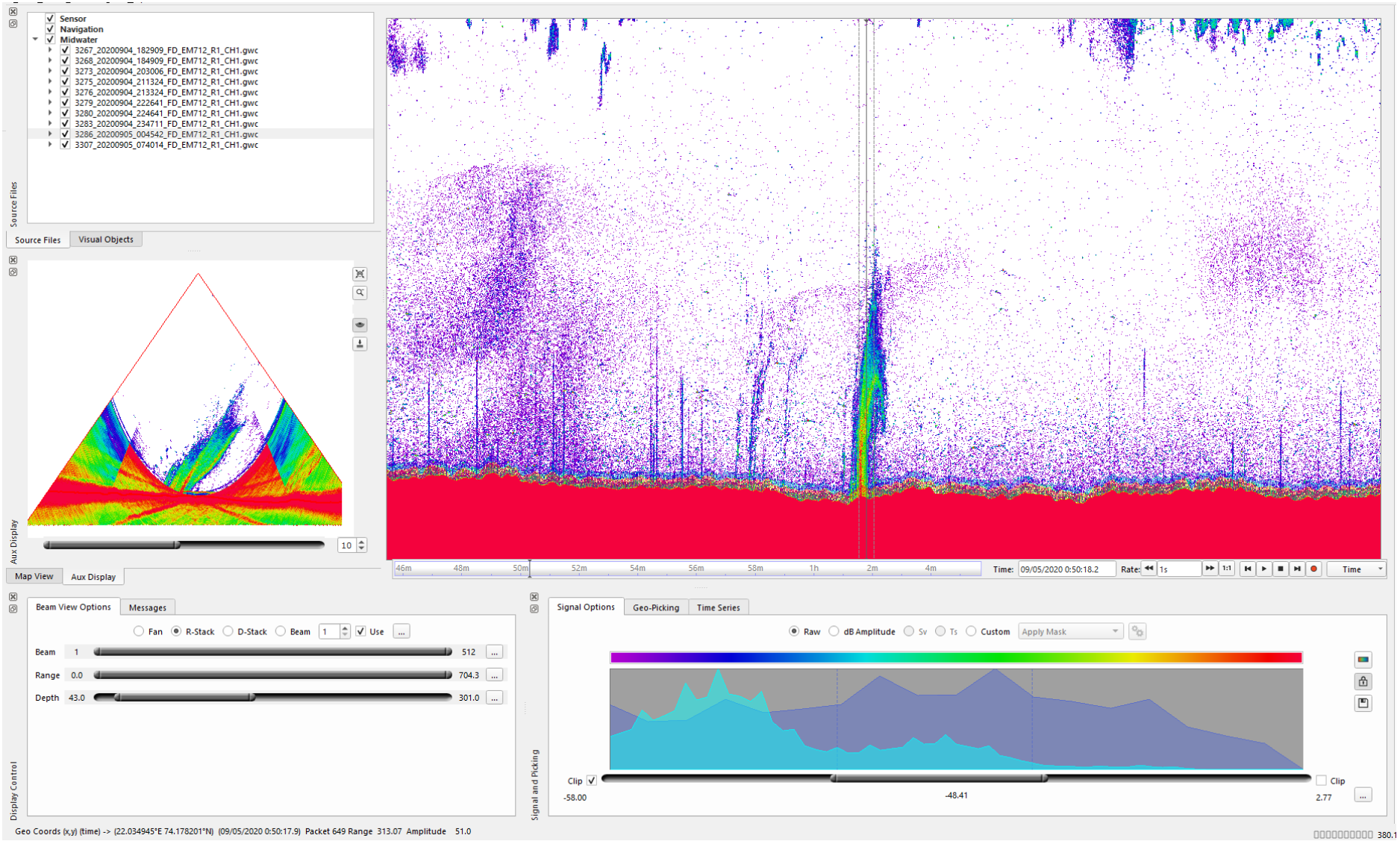


Figure 36. Gas flare from line 3286, fgmg-2020-TR-NS02-NS03-c2 showed on Fan view and stack view. Magnitude 5, Confidence 90%.

5. CONCLUSIONS

Flares are observed with high confidence in the survey locations and are distributed all over the study area. A relation to the subsurface structural features can be observed based on the regional tectonic map of the region. A total of 357 certain and uncertain gas flares have been found in the water column data, of which 36 are magnitude 4 and above.

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