Scientific Research to Characterize and Localize the Windsor Hum: Final Report

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1. Introduction

Approximately three years ago, the citizens of Windsor, Ontario began noticing and reporting a bothersome and persistent noise, most noticeable in Southern Windsor and La Salle. The noise, now popularly termed the 'Windsor Hum', is commonly described as either a deep, low-frequency hum, like a furnace or an idling diesel truck or as a deep, pulsating and vibrating noise, which is perceived more as a sensation rather than an audible sound.

The Ontario Ministry of the Environment (MOE) has been receiving ongoing complaints since March 2011 related to the Windsor Hum. The reports described the rumblings as intermittent in nature, but often persisting for several hours. From June 2011 to August 2011, Natural Resources Canada (NRCan) performed a seismic study in an attempt to identify the nature (underground or airborne) source of the rumblings and the probable location (Bent and Withgold, 2011). While this seismic study did not ascertain the exact source of the Hum, it suggested Zug Island as the most probable location of a monotone signal correlated with Hum reports by the public and having a dominant frequency of approximately 35 Hz. The report also suggested that the signal was an acoustic wave propagating through the air rather than a seismic wave traveling through the ground. Based on these initial results, an acoustic study, which would further characterize the nature and location of the Hum seemed warranted.

In January of 2013, the Department of Foreign Affairs and International Trade (DFAIT) contracted Western University and University of Windsor to conduct a joint acoustic study pertaining to the Windsor Hum. The role of Western University was to deploy two portable infrasound arrays in the Windsor area over the period of approximately one month to monitor the Hum and determine its frequency, direction and source. The portable array instrumentation was provided by Natural Resources Canada (NRCan).

The Infrasound array deployment occurred during late February/early March, 2013 and terminated on April 8, 2013. This report summarizes the array deployments, the data examination and analysis, the findings and ancillary data collection associated with local Hum reports. A goal of this study was to geolocate (through cross bearing association) any commonly detected signals at both arrays occurring during time periods when the Hum was reported based on public reports. The temporal and spectral characteristics of signals detected at the arrays were

also examined during such time periods to try and identify the most probable linkage of public Hum reports to acoustic signals.

1.1 Low Frequency Sound

Infrasound is low frequency sound just below the threshold of the human hearing range of 20 Hz (cycles per second) extending down to the natural oscillation of the atmosphere (~0.01 Hz). Since the attenuation of sound is proportional to the square of the frequency, low frequency sound can efficiently propagate over long distances (Beer, 1974). The frequency spectrum of sound and its nomenclature are shown in Figure 1. Hereafter, we refer to the frequencies below 20 Hz as infrasound and the frequencies from 20 – 125 Hz as low frequency sound. Noise is defined as any undesired and unwarranted disturbance within a useful frequency band (ANSI, 1994; Berglund et al, 1999); hereafter, we will refer to the Hum in terms of both sound and noise. Note that for low frequency sound, typical audible sound propagation ranges are of the order of several kilometers to tens of kilometers for industrial sources (ANSI, S1.26-1995), with the actual range strongly dependent on the source pressure level, atmospheric winds, humidity and local topography.

There are many natural and anthropogenic sources of infrasound and low frequency sound. Some of the natural sources are ocean waves, thunder, air turbulence, volcanoes, lightning, aurora, and meteors (von Gierke and Parker, 1976; Backteman et al, 1983a; ReVelle, 1976). The sources of anthropogenic origin are airplanes, trucks, machinery, and air-conditioning/heating/ ventilation systems (Blazier, 1981; Job, 1988; Berglund et al, 1996). Exposure to low-frequency noise is common in modern urban environments, especially in heavily industrialized regions. It is also less attenuated by various structures than high frequency sound, and it can cause rattling of walls and other objects (Hood and Leventhall, 1971; Berglund et al, 1996). Even though low frequency sound has been studied for several decades, only in recent years has it received much attention in terms of its effects on humans, especially pertaining to physiological and psychological effects, annoyance levels and subjective perceptions in urban and industrialized areas (e.g. Bryan, 1976; Berglund et al, 2000; Fields, 2001; Cohen and Weinstein, 2010). The reports of a persistent annoyance from sound are not new. A hum-type annoyance has been heard at locations

worldwide (Deming, 2004). For example, low frequency rumbles, which also caused pressure in the ears, were reported in West London, UK (Broner, 1978; Cowan, 2003). Vasudevan and Gordon (1977) recognized that low frequency throbbing noise is '*very probably a real phenomenon and not imagined or self-generated*'. Leventhall (2003) described the Hum as a diesel engine idling in the distance, a steady throb, rumbling and pulsing.

Low frequency sound can invoke subjective reactions, as determined by various laboratory, field and in the community studies. The relative proportion of sources leading to complaints associated with low frequency nose is shown in Figure 2 (Waye, 2011). Humans tend to react more to artificial noise (von Gierke and Parker, 1976; Job, 1988). Impulsive noise sources, such as quarry blasting, are known to cause higher levels of subjective reactions compared to non-impulsive noise of the same level (Job, 1988; Bullen et al, 1991). Another issue is that masking of low frequency sound by the surrounding higher frequencies tends to cease during night time when the majority of the population are asleep. At that time low frequencies tend to dominate, thus contributing to increased levels of annoyance and disturbance (Persson and Bjorkman, 1988; Berglund et al, 1984; Berglund et al, 1996). A paired comparison test carried out by Kraemer (1973) has revealed that the annoyance peaks at certain frequency combinations (30 – 50 Hz), especially if it at a constant loudness level. Another study (Vasudevan and Gordon, 1977) has determined that the throbbing levels mostly occur in the 30-40 Hz frequency range.

This study investigates both inaudible (below 20 Hz) and audible frequencies (up to 125 Hz) in order to determine the dominant frequency and geolocation of the Hum based on correlating infrasound array signals with local Hum reports form the public.

2. Data Collection and Analysis

2.1 Field Equipment: Portable Infrasound Arrays

The portable microbarograph sensors used for this study are Chaparral 25 microphones manufactured by Chaparral Physics at the University of Alaska. The digitizers are Taurus models manufactured by Nanometrics, which sample at 250 Hz. The sampling rate of 250 Hz limits the highest resolvable frequency (the Nyquist frequency) to 125 Hz, well into the audible range.

Four porous garden hoses were attached to each one of the sensors to reduce local wind noise and turbulence.

Two portable infrasound arrays, henceforth referred to as Array 1 and Array 2, comprised of four sensors (elements) each, were deployed in the Windsor area (Figure 3). Array 2 was deployed on February 20, 2013 directly across from Zug Island (~1.5 km away) on Transport Canada (TC) property, while Array 1 was deployed on March 4, 2013 south of Zug Island (~3.5 km away) on Windsor Salt (WS) property. Array 1 is approximately 3 km South of Array 2. Both arrays were set up with the four elements deployed in a triangular formation with the three outer elements approximately 20m away from the centre element (Figure 4). The positions of individual sensors were measured with a high accuracy differential GPS (dGPS) unit (absolute accuracy of 10cm). The small separation between the elements was designed to optimize the arrays for detection and processing of frequencies well above 20 Hz. One disadvantage of such small apertures however, is the possibility of spatial aliasing (Christie and Campus, 2010).

Aside from their proximity to Zug Island, both the TC and WS sites had 24 hour security, which made them excellent location choices for this study. Much of the choice for the sites was dictated by the logistics of security and ability to obtain permission for siting for the full month of the study. The equipment and site layout for Array 2 is shown in Figures 4 – 7, while Array 1 is shown in Figures 8 – 10. Array 2 was placed at a site with heavy vegetation cover, and was secluded, while Array 1 was in an open field and very close to the river bank. A possible issue with the TC site (Array 2) was continuous construction activity and ongoing truck traffic proximal to the array. Additionally, sand/dirt piles being used for bridge construction blocked the direct view to the river and may possibly have interfered with horizontally travelling sound waves efficiently reaching the array from across the river.

The data was continuously streamed to NRCan, and then sent to a Western University server one to two days later. There was one instance of data dropout on March 12, which had to be resolved by going to both sites and manually rebooting the digitizers. Both arrays were decommissioned on April 8, 2013, after 36 days of operation.

2.2 Resident Reports During the Monitoring Period

To search for possible signals in the infrasound array data associated with the Hum, it was essential to have some indication of Hum occurrences (date, time, duration) and the type of sound (low frequency hum, vibrations, pulses) experienced by people in Windsor. This permits correlation of infrasound signals with Hum reports. In this regard, we established a dedicated e-mail (reportwindsorhum@gmail.com) for residents to report Hum detections in addition to a reporting form set up through the Department of Physics and Astronomy website, Western University:
[http://physics.uwo.ca/windsor_hum_form.html] and publically announced to residents through local media. These reports were compiled (Appendix 1a) and subsequently used to correlate with possible acoustic signals. As part of this study we also collaborated with the Ontario Ministry of the Environment (MOE) to receive reports sent to them by the public. However they did not receive any reports from mid-February, 2013, so all subsequent analysis in this report is based on the study email/website dedicated reports.

To portray the nature and manifestation of the Hum, the local residents (herein referred to as The Windsor/Essex County Hum group) have also provided a number of sound recordings taken with their personal devices. From residents' reports, the sounds and annoyance level associated with the Hum were generally more subtle and less prominent during the study period (Feb 20 – Apr 8, 2013) than previously experienced (e.g. during 2012). It is not certain whether this is due to seasonal effects or some other reasons. Qualitatively, many reports suggest that the sounds are the most prominent on cloudy days. The propagation of sound in real air depends on meteorological factors such as wind, frequency and humidity. The reported sounds associated with the Hum fell into several distinct categories:

1. An idling engine-type sound (also identified as a furnace sound),
2. Pulsing or rumblings
3. Vibrations.

Residents noted that some or all categories could be reported at any one time. On a number of occasions some residents explicitly reported a quiet (Hum-free) day while others experienced substantial annoyance from the Hum. The nature of these complaints is broadly consistent with other witness descriptions of low frequency sound as described in the preceding sections.

We also performed a comprehensive follow-up survey (questionnaire) which was both made available on-line to The Windsor/Essex County Hum group with the help of the local resident, Mr. Gary Grosse and e-mailed to all those who were reporting the Hum using our internal reporting system. To protect privacy of those reporting the Hum, their individual names are not listed in the report and only place marks, rather than full addresses, are mapped for the purpose of correlating the complaints with the reported timing, observer reported direction and nature of the Hum (Figure A1-1, Figure A1-2). The most commonly reported general direction of the Hum is from the West-Northwest for all locations east of the River (Windsor and LaSalle) and East-Southeast from the west of the River (Michigan). The results of the follow-up survey are shown in Appendix 1b.

2.3 Signal Analysis and Methodology

The Windsor area is exceedingly noisy acoustically, as is the case for most major urban areas. This complicated the airwave signal analysis and geolocation as often multiple sources from multiple directions are actively producing acoustic signals at any given time. Both infrasound arrays were equipped with extremely sensitive microphones, capable of picking up very slight changes in air pressure (one part in a millionth of the ambient atmospheric pressure under ideal conditions). The raw waveforms were initially processed and analysed in MatSeis 1.7, which is used for basic filtering and cross-correlating low frequency sound waveforms between array elements (Figure 11). Associated spectrograms (distribution of acoustic energy as a function of frequency and time) were used to investigate signals potentially linked to the Hum and to determine the dominant frequency. However, since MatSeis 1.7 is not sufficiently sensitive nor is it optimized for very noisy arrays (such as in this study), the Progressive Multi-Channel Correlation Method (PMCC) was used to search for pressure airwave signals in more detail. PMCC is very efficient for detecting low amplitude, coherent infrasound signals (Cansi, 1995; Le Pichon and Cansi, 2003), which is especially important for noisy sites. It utilizes a sequence of frequency bands together with user-specified time windows to identify ‘families’, or detections associated with a single coherent signal, in effect identifying the timing and frequency range for a coherent signal. This family association among PMCC ‘pixels’ is done by specifying allowed ranges or thresholds for inclusion in a family across a number of parameters, which may

include the signal timing, back (arrival) azimuth, coherence, correlation and trace velocity. Description of the technique and application of PMCC to infrasonic array processing can be found in (Brachet et al., 2010).

We performed a signal search in all frequencies between 5 – 125 Hz for a number of time segments including all intervals where public reports of the Hum were made as well as a number of randomly selected control intervals. Since the previous seismic study, conducted by NRCan, had identified the frequency range of interest (approximately 35 Hz), particular attention was paid to signals in this spectral region with the goal of establishing arrival directions for a possible source. It should be noted that even if a probable signal is found, unless both arrays detect the same signal, it is not possible to determine the location of the source, as there is no precise indication of the distance the signal travelled before reaching any one array. Only back azimuth cross-bearing intersections from both arrays would provide a geolocation.

Several randomly selected time segments were analysed to establish a baseline of typical airwave signals received at each array and determine overall dominant frequencies and general directions of arrival. The findings will be discussed in the Results section.

Our methodology was to search for possible signals at both arrays using PMCC within 30-60 minutes of a public Hum report. Since the high sampling rate (250 Hz vs. usual 20-50 Hz for a typical infrasound array) is taxing on the software and thus computing time, only data segments of 30 – 60 min could be analysed at any one time. Therefore, it was necessary to perform successive analysis on a number of waveform sections in a long time segment (for example, a time period of 5 hours would have to be analysed in at least 5 separate data chunks). To initially identify the possible signals associated with the Hum, a number of PMCC settings were manually tested and then modified to attempt to optimize the search for signals of interest. Several test data sets (15 - 30 min each) corresponding to the time intervals where Hum activity was reported by residents were analysed with various settings until the possible Hum signal was identified. Trace velocities less than 0.290 km/s do not belong to the infrasound/low frequency sound spectrum (e.g.Le Pichon and Cansi, 2003); thus, such signals were not classified as a viable detection.

The data from Array 2, being operational before Array 1was analysed first. Nearly all the signals seen at Array 2 come from a single direction. Array 1 was much nosier than Array 2, with a

number of distinct signals in discrete frequency ‘bands’ and ‘packets’ arriving from multiple directions at various speeds at the time of Hum reports.

3. Results

The final PMCC results are best displayed through a series of plots. These can be found in the Figures section, with captions further explaining the context and meaning of each plot. The the color intensity is a representation of relative intensities, rather than absolute. The PMCC results windows (e.g. Figure 12) are comprised of 5 sub-windows. These are (starting from the top): (i) correlation – a measure of the signal coherency between various elements across the array; (ii) amplitude – root mean square of the signal amplitude across all elements in Pascal (Pa); (iii) azimuth – apparent direction of the signal arrival in degrees, measured clockwise from north; (iv) speed – apparent trace velocity in km/s across array. A horizontally travelling airwave is typically in the trace speed range of 0.330 km/s (near the ambient sound speed), higher speeds >0.40 km/s indicate steeper signal arrivals; (v) the lowermost window is a pressure versus time plot of the signal as recorded by one of four array elements. The horizontal axis represents the time segment in UT, while the vertical axis represents the frequency content in Hz. The polar plots (e.g. Figure 13, left inset) represent the most likely direction of the signal arrival at the highest amplitude and include the signal speed (km/s), azimuth (degrees), frequency (Hz) and signal amplitude (Pa) with their respective uncertainties for a chosen detection family. The magnitude of the signal amplitude is generally in the range of several tenths of a Pascal. For comparison, the atmospheric pressure at sea level is 101,325 Pa. Some of the polar plots showing arrival directions are shown side-by-side with a Google map plot of the area for better visualization. The solid yellow line on the maps shows the approximate signal energy direction. The dashed lines represent the outermost weaker signals and their respective directions, essentially bounding the uncertainty bearing of the detection. The time is shown in Universal Time (UT), while the time of the reports (Appendix 1) is in local time (EDT); EDT being 4 hours behind UT.

The entire frequency spectrum (1 – 125 Hz) was first examined on several test data sets to establish the baseline. Examples of this baseline are shown in Figures 14 – 16.

Even though they were stationed about 3 km apart from each other, Array 1 and Array 2 show very different intrinsic signal characteristics, most probably due to the local site (topography), prevailing winds relative to possible sources and ambient noise conditions.

3.1 Array 2 (Transport Canada Site)

The detailed analyses have revealed that the airwave signals at Array 2 mostly originate from the direction of approximately 60 degrees, that is from downtown Windsor, across almost all frequencies. A steady signal at about 25 – 30 Hz, present most of the time, was also detected (Figure 17). Another, much weaker signal, present only occasionally (mostly during the Hum activity as reported by the residents), occupies the 35 Hz frequency band. The two signals, 30 and 35 Hz, seem to be interconnected, as the 'peaks' or pockets of energy occur at the same time in both frequency bands (Figure 18 – 20). The apparent direction of arrival for all these signals always points in the 60±10 degree direction from the Array 2 site. Even though the effect of cross-winds was not taken into consideration, one would not expect the direction to be modified more than a few degrees from this 60 degree direction as the geostrophic winds typically arrive from the W or NW.

We noted that the construction of a new cross-border bridge underway during the time of our deployment at the river may have created a physical barrier possibly preventing free propagation of airwaves coming from the direction of the United States at this site.

3.2 Array 1 (Windsor Salt)

The Array 1 site is very noisy compared to the Array 2 site, with various signals coming from nearly all the directions (e.g. Figure A2-A75). Below 50 Hz, there are several distinct frequency 'bands' in which coherent signal energy is most prominent (relative to the background). The frequencies between 10 – 15 Hz usually arrive at a steep angle (high speed) and from the

azimuth of 1 degree; however there are no signal 'families' associated with these arrivals and there are no signal families in this band. The next distinct frequency band commonly visible is just above 20 Hz (Figure 23), and is associated with high trace speeds coming from circa 350 degrees azimuth. These frequencies are always present, and as such may or may not be associated with the Hum. We found and identified two additional frequencies of interest which are present at irregular intervals, one at approximately 28 – 30 Hz and another one at approximately 35 Hz (e.g. Figure 23). These two frequencies are particularly prominent during the Hum activity periods reported by local residents. The coherent and strongly correlated signal comes either in distinct 'packets', each lasting for several minutes (usually 35 Hz, see Figure A2-34, Figure A2-37 for examples) or as a semi-continuous signal (mostly near 30 Hz) lasting from tens of minutes to several hours and with sporadic bursts (e.g. Figure 25) and showing fluctuating amplitude/coherency. The direction of arrival of signals within the 30 – 35 Hz frequency band at Array 1, based on 54 separate occurrences within the data sample analysed is 265.2 ± 4.2 degrees (Figure 27). The effect of the cross-winds on backazimuth was ignored for this study.

On April 7, 2013, the pulse-like features were seen on the waveforms across all channels. The frequency spectrum also showed a pulsation-like signal, spanning from about 10 Hz to nearly 40 Hz (e.g. Figures A2-51, A2-52, A2-80, A2-81). Even though these pulses did coincide with reports of rumbles and pulses heard and felt by some residents, in other instances when the pulsing-type of Hum was reported, such features were not seen (e.g. April 5, 2013, Figure A2-39). Thus we do not find a completely consistent correlation between the qualitative Hum report categories and the spectral character of the most probable signals associated with the Hum at Array 1.

For better visualization and understanding, specific instances and characteristics of these signals are discussed in figure captions in the Figures section. It is not clear which one of these two frequencies (30 Hz or 35 Hz) is associated with a specific Hum category reported. As previously mentioned, the Hum comes in several categories, ranging from the persistent idling/droning/furnace noise to the pulsing/rumbling/vibrations. Based on the association of the reports with the specific signal signatures, the most consistent (though not universal) associations seem to suggest that the droning/idling may be associated with the 30 Hz frequency, while the pulses may come from the 35 Hz frequency. Since the data sample only covers the time period of

just over a month and during the Hum ‘downtime’ relative to the usual activity, it is difficult to pinpoint with much certainty which type of annoyance is associated with a specific frequency band or if in fact, they are producing the Hum.

In very rare instances (<3% of the families identified), there was some indication of a possible airwave originating from 360/0 degrees (e.g. Figure 21), which is in the general direction of Zug Island; however, this signal is distinct from the signals coming from a bearing of approximately 270 degrees. First, it is not readily associated with any signal ‘families’, and second, the trace velocity is high, indicative of a steeply arriving airwave. If this is truly a signal, the high trace velocity implies that it is coming from either an air source (air traffic) or a ducted airwave originating at a distance of at least one duct "hop" allowing the originating ground airwave to refract back to the ground. The implication is that this signal occurs only sporadically or that it is always present but is usually masked by the more dominant signal at Array 1 from the direction of 270 degrees. In either case, it is not well correlated to Hum reports.

We did also attempt to perform ray trace propagation modeling in an effort to determine propagation channels and possible atmospheric influences as well as sources. However, without a single defined location source and the extremely short propagation distances this methodology proved ineffective.

4. Findings and Conclusions

Two infrasound arrays were deployed from late February to early March 2013 in the Windsor and La Salle area. In total, they were operating for a period of just over a month.

Our findings are:

1. We do not find common signals at both arrays which could plausibly be associated with the Hum. We are unable to geolocate a definite source for the Hum using common cross-bearings.
2. Array 2 (Transport Canada Site) shows acoustic arrivals from the direction of downtown Windsor (Figure 29). No clear signals are seen at this site which can be associated with

common signals at Array 1 (based on timing, azimuth or spectral content). Some public Hum reports coincide with an infrequent 35 Hz signal at this site which also appears to be coming from downtown Windsor. This may indicate either a source of 35 Hz in downtown Windsor or that the actual direction of the 35 Hz signal is being masked by the consistent, strong acoustic signal from the center of Windsor.

3. Array 1 (Windsor Salt Site) shows a wide spectrum of signals from nearly all directions.
4. Array 1 shows signals at the time of public Hum reports predominantly in the 30 Hz and 35 Hz frequency bands, suggesting these are the most likely signal among those we have detected to be associated with the Hum. This is consistent with the earlier NRCan seismic study. The point of origin of the airwave is most probably somewhere along the line from Array 2 in the 265±4 degrees (nearly due west) direction (e.g. Figure 28). Without a second bearing we cannot definitely pinpoint the source, other than to say that it could be as close as the waterline, or much further away.
5. We note that the bearing from Array 1 to the most probable source of the Hum points well to the South of Zug Island. The bulk of our observations from both stations do not support the hypothesis that the source of the Hum emanates from Zug Island.

The complexities of acoustic propagation in the local Windsor conditions, including geology (Windsor is a syncline), vegetation, ground reflections, propagation paths, interference, turbulence, etc., may all or in part play a role in sound propagation. While it is not possible to ascertain the exact source of the Hum, possible sources may include quarry activity or industrial ventilation systems. For example, quarry activity is known to produce impulsive sounds (Job, 1988) and there could be some coupling mechanism of line blasting with the ventilation/release systems.

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Figures

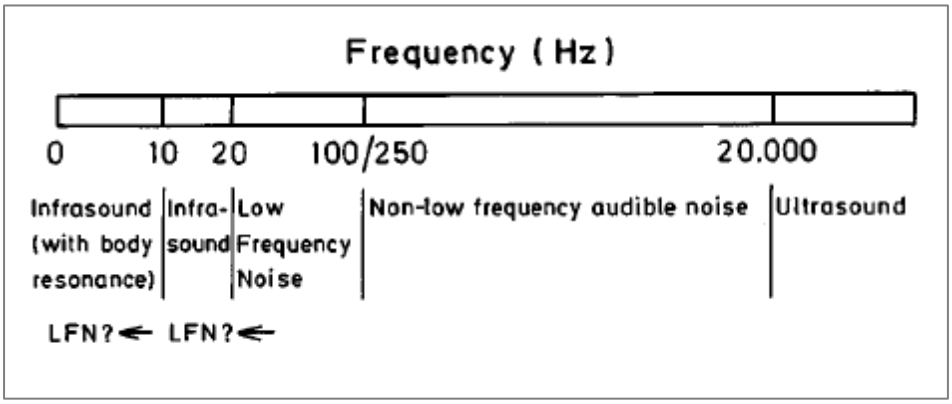


Figure 1: Sound regimes as a function of frequency. From Berglund et al. (1996)

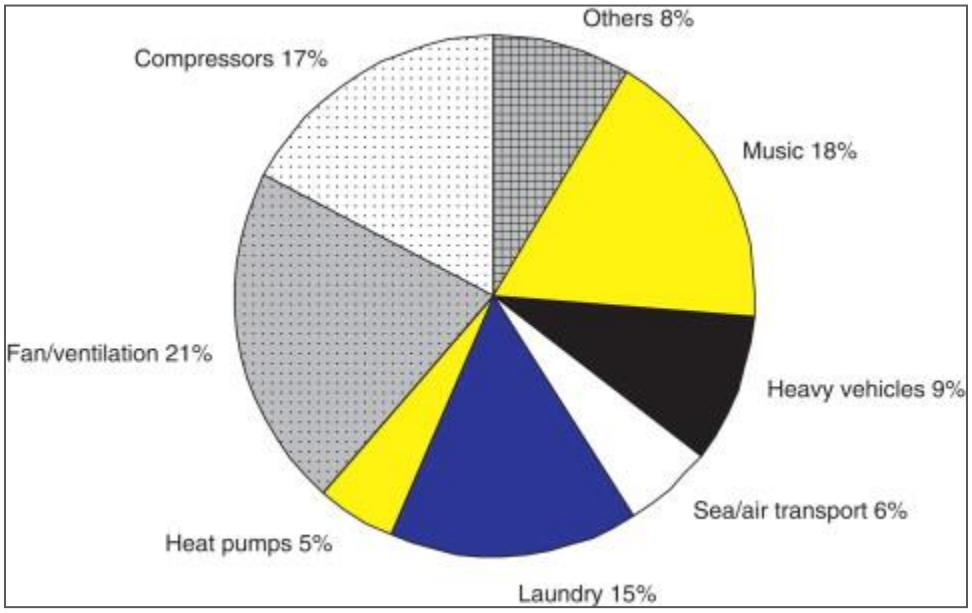


Figure 2: An estimate of the relative proportion of the sources associated with complaints of low frequency noise. Reprinted from Waye (2011)

Figure 3: Map showing the locations of two infrasonic arrays deployed in Windsor. Array 2 was located across from Zug Island (top), while Array 1 was stationed ~3 km further south (bottom).

Figure 4: Map showing the configuration of Array 2 at Transport Canada (TC) site

Figure 5: Picture showing the Array2 installation (Centre Element) at the TC site

Figure 6: Picture showing the site and the Array 2 installation (North Element) at the TC site

Figure 7: Picture showing the site and the Array 2 installation (SE Element) at the TC site

Figure 8: Map showing the configuration of Array 1 at the Windsor Salt mine (WS) site

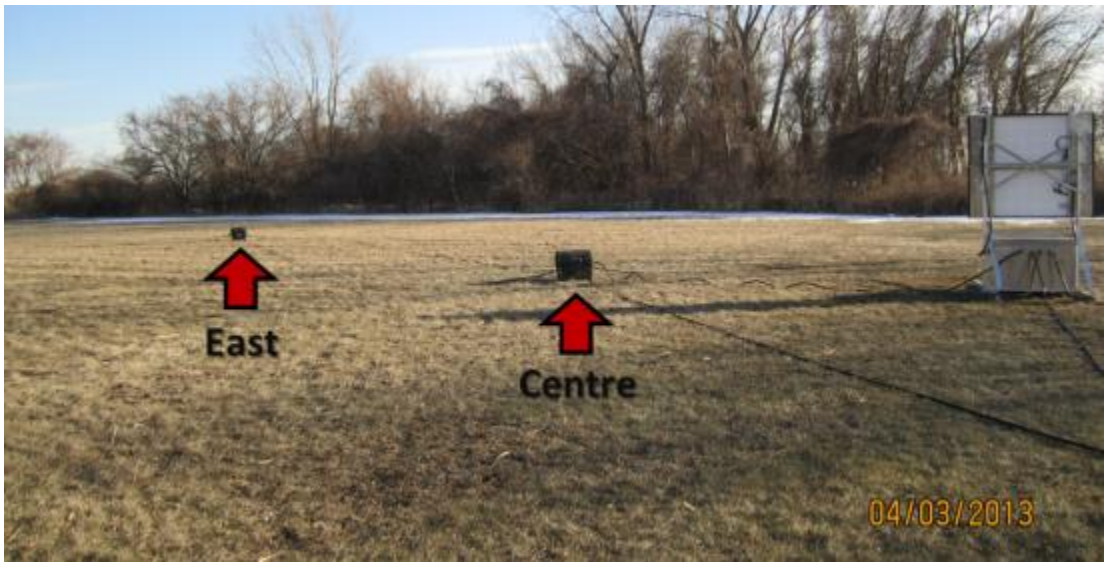


Figure 9: The array 1 installation (East and Centre Element) at the WS site

Figure 10: The Array 1 North Element at the WS site

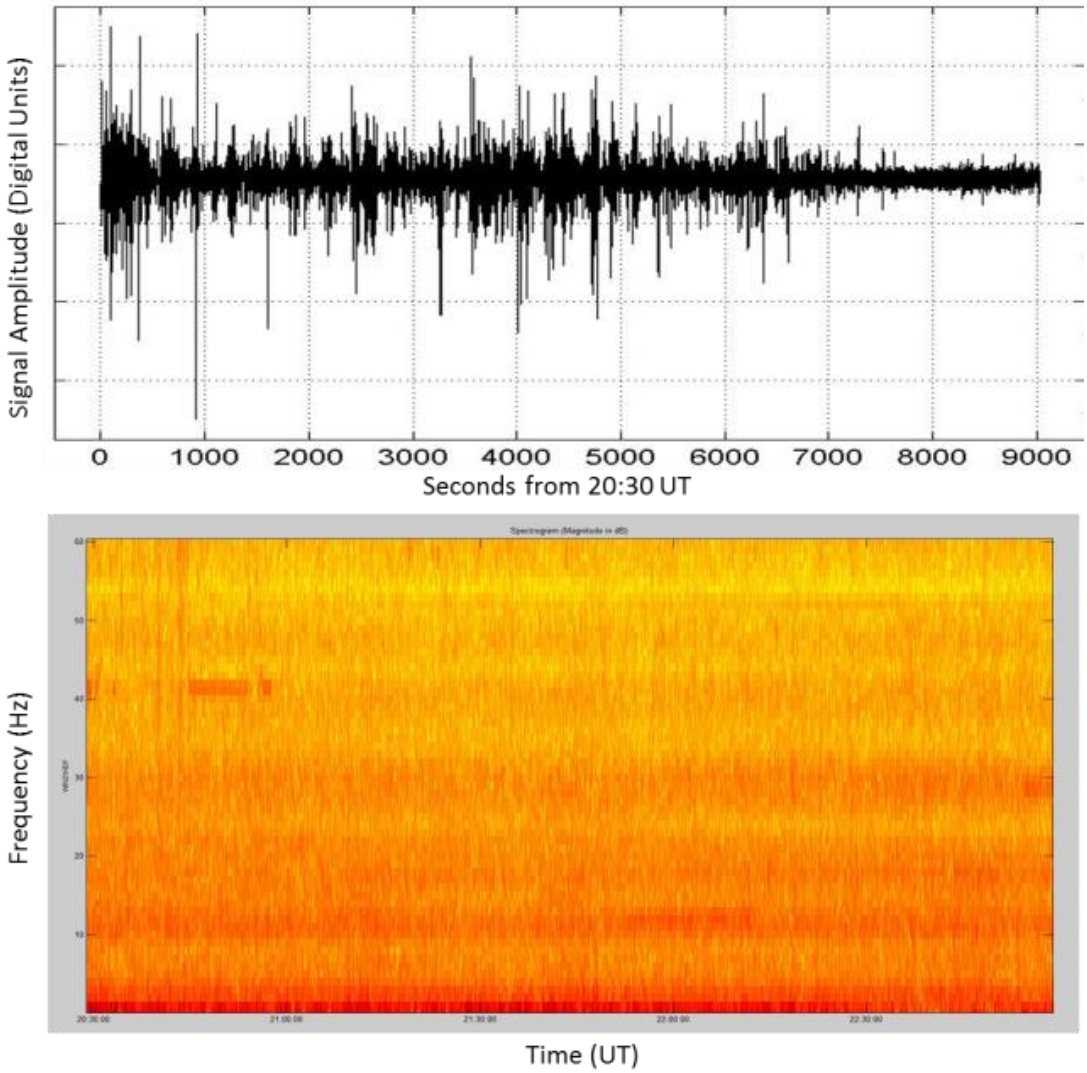


Figure 11: Waveform (above) and spectrogram (below) of the signals received on March 18, 2013 starting at 20:30 UT at Array 2 (channel 1). Processed in MatSeis 1.7.

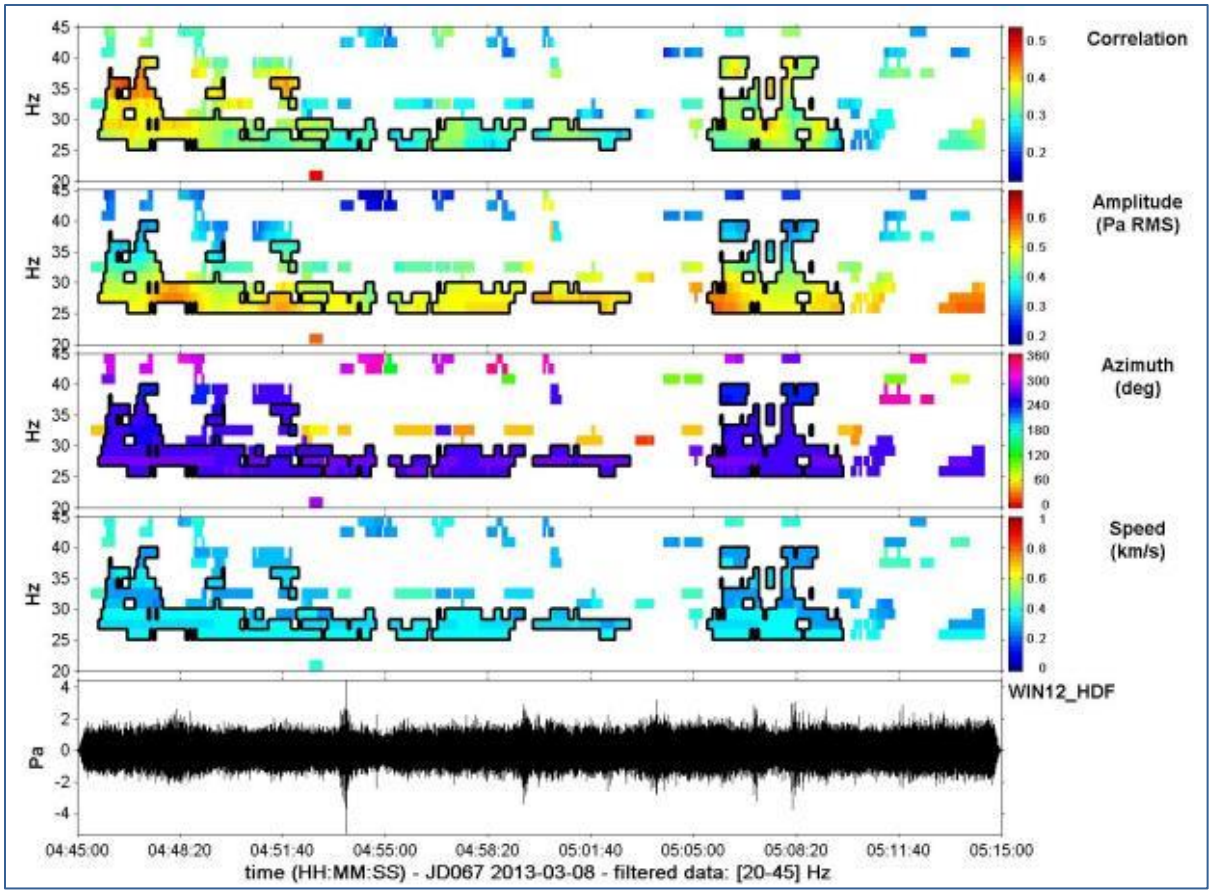


Figure 12: The PMCC results main window for March 8, 2013, from 04:45:00 – 05:15:00 UT. The sub windows, starting from the top, are: Correlation – a measure of the signal correlation in the pressure vs. time record of each array element; Amplitude – root mean square of the signal amplitude in Pascals (Pa); Azimuth – apparent direction of the signal arrival in degrees, measured clockwise from north; Speed – apparent trace signal velocity in km/s across the array. Horizontally travelling airwaves typically have speeds in the range of 0.330 km/s, higher speeds >0.40 km/s indicate steeper arrivals; the lowermost window is the signal as recorded by the north element. 'Boxed' regions indicate PMCC signal 'families' corresponding to individual coherent signal detections. The horizontal axis represents the time segment in UT, while the vertical axis represents the frequency content in Hz.

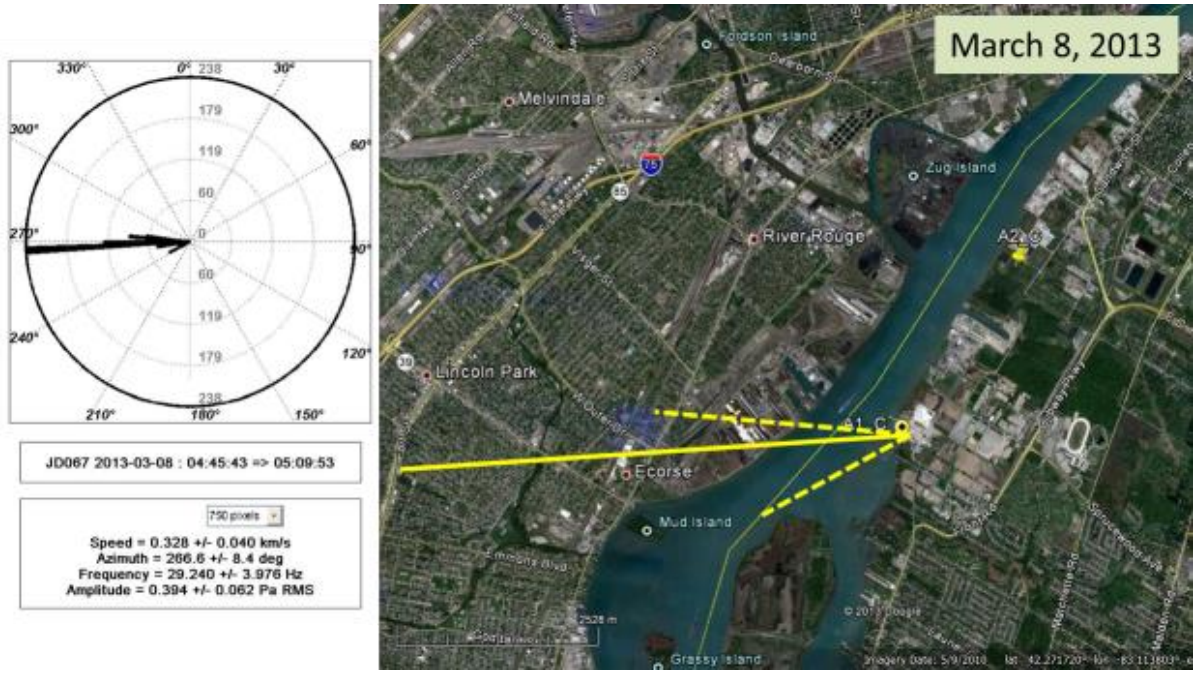


Figure 13: Left: The polar plot from PMCC indicates the direction of the signal as well as the amplitude strength. The dominant frequency of the signal is 29 Hz. Right: The signal direction translated to a local map of the area. The solid line points to the most probable direction of the 29 Hz signal as determined by PMCC. The dashed lines indicate the azimuthal range of signal arrival. The length of the line is proportional to the signal strength. While the majority of public Hum reports during the period of this study came from the region east of the river, one came from Michigan and another one from north of Windsor. A1_C is the location of Array 1 at Windsor Salt, while A2_C is the location of Array 2 at the Transport Canada site.

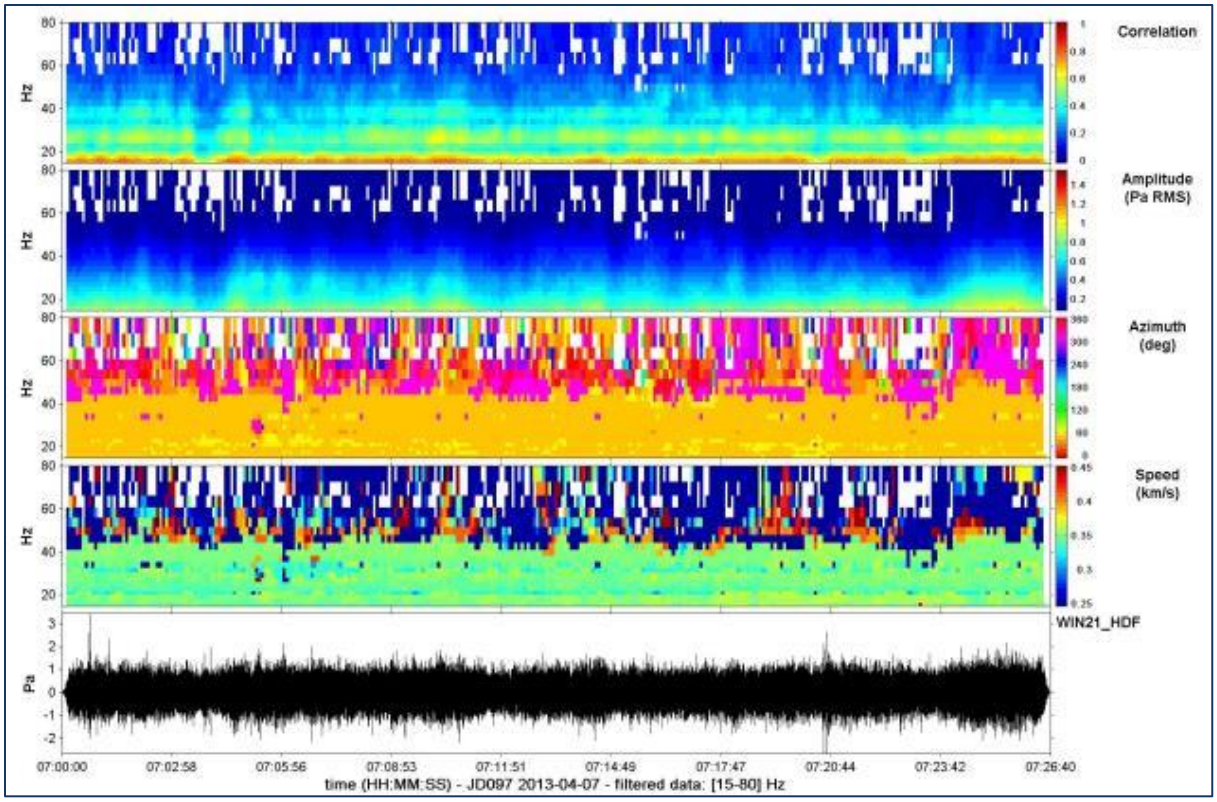


Figure 14: The frequency content as seen at Array 2 on April 7, 2013 from 07:00:00 – 07:26:40 UT. Yellow shades in the Azimuth window correspond to an arrival azimuth from 60 degrees.

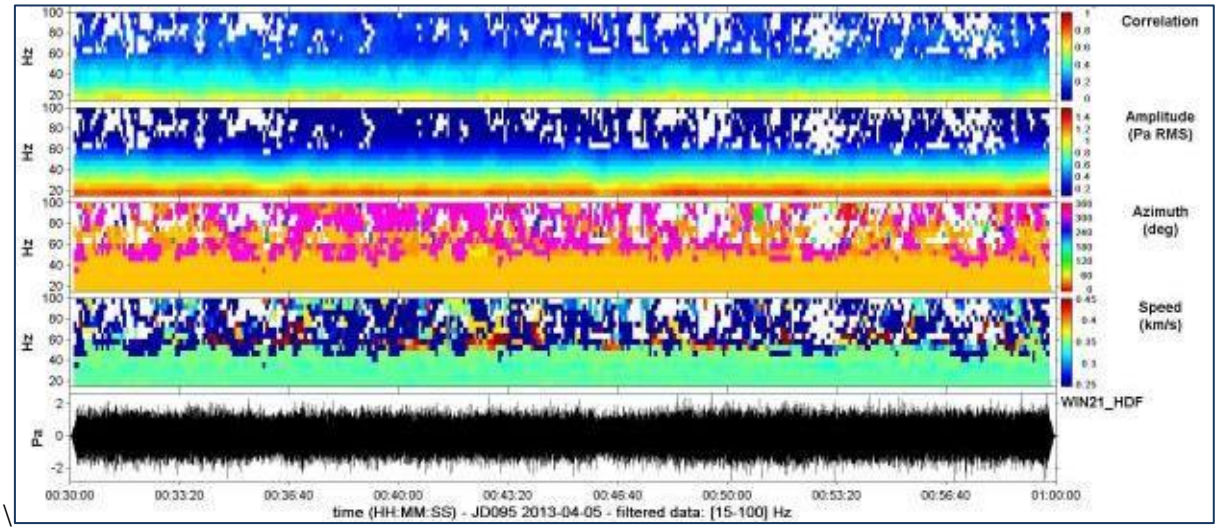


Figure 15: Another example of the signal content as seen at Array 2 on April 5, 2013 from 00:30:00 – 01:00:00 UT. Yellow shades in the Azimuth window correspond to the azimuth of 60 degrees.

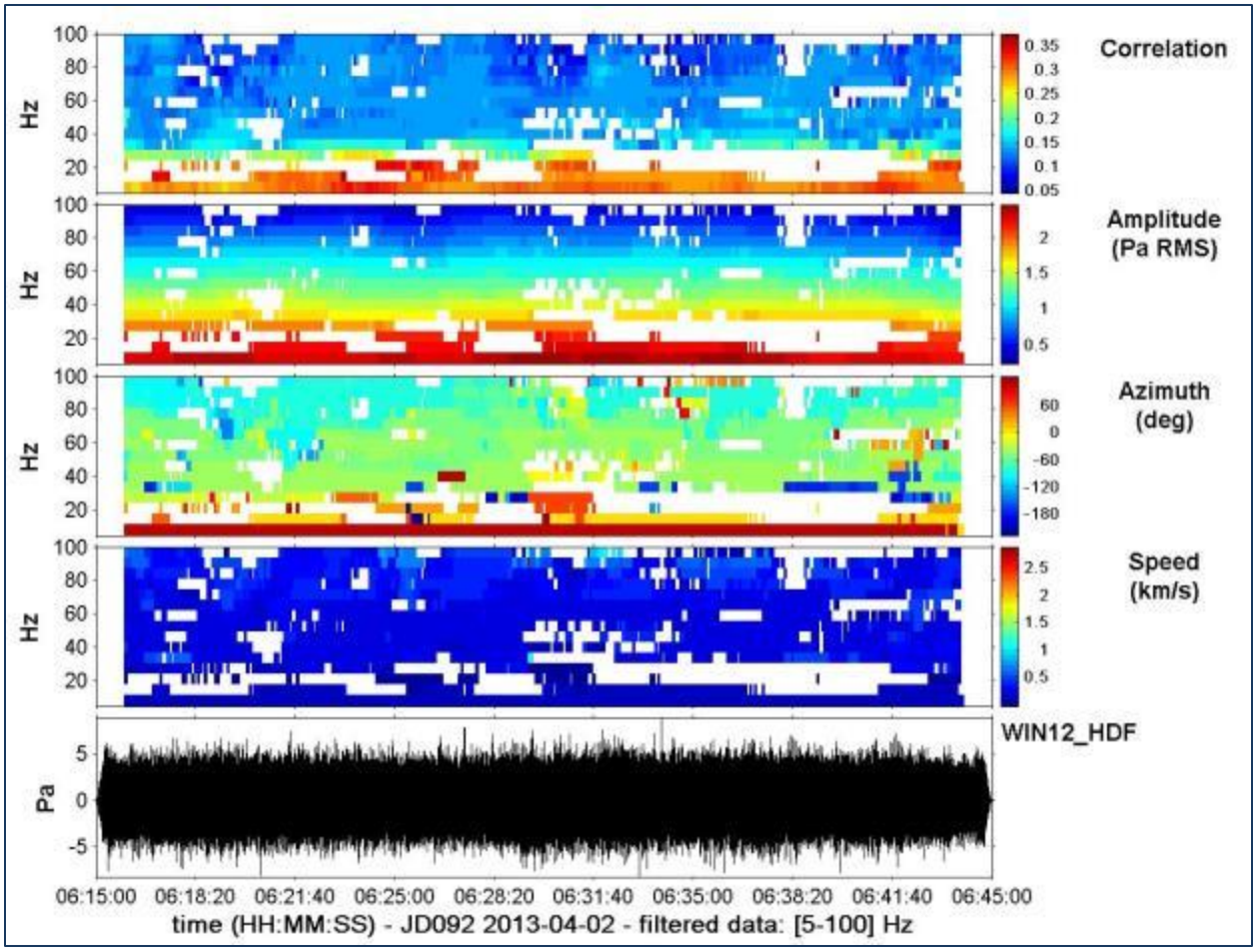


Figure 16: The signal content as seen at Array 1 on April 2, 2013 from 06:15:00 – 06:45:00 UT. Green shades in the Azimuth window correspond to an azimuth of 270 degrees.

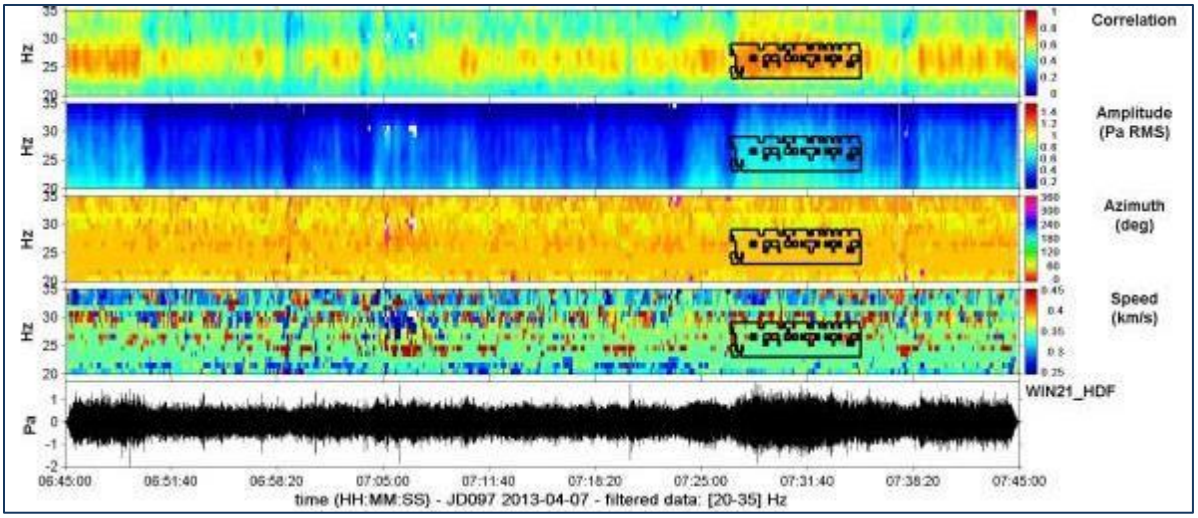


Figure 17: Signal as received at Array 2 on April 7, 2013 from 06:45:00 – 07:45:00 UT. The highlighted region (black box) is an identified family in the time segment from 07:26:53 – 07:35:03 UT. The dominant frequency of this family is 25.8 ± 1.9 Hz. The back azimuth is 52.5 ± 3.5 degrees.

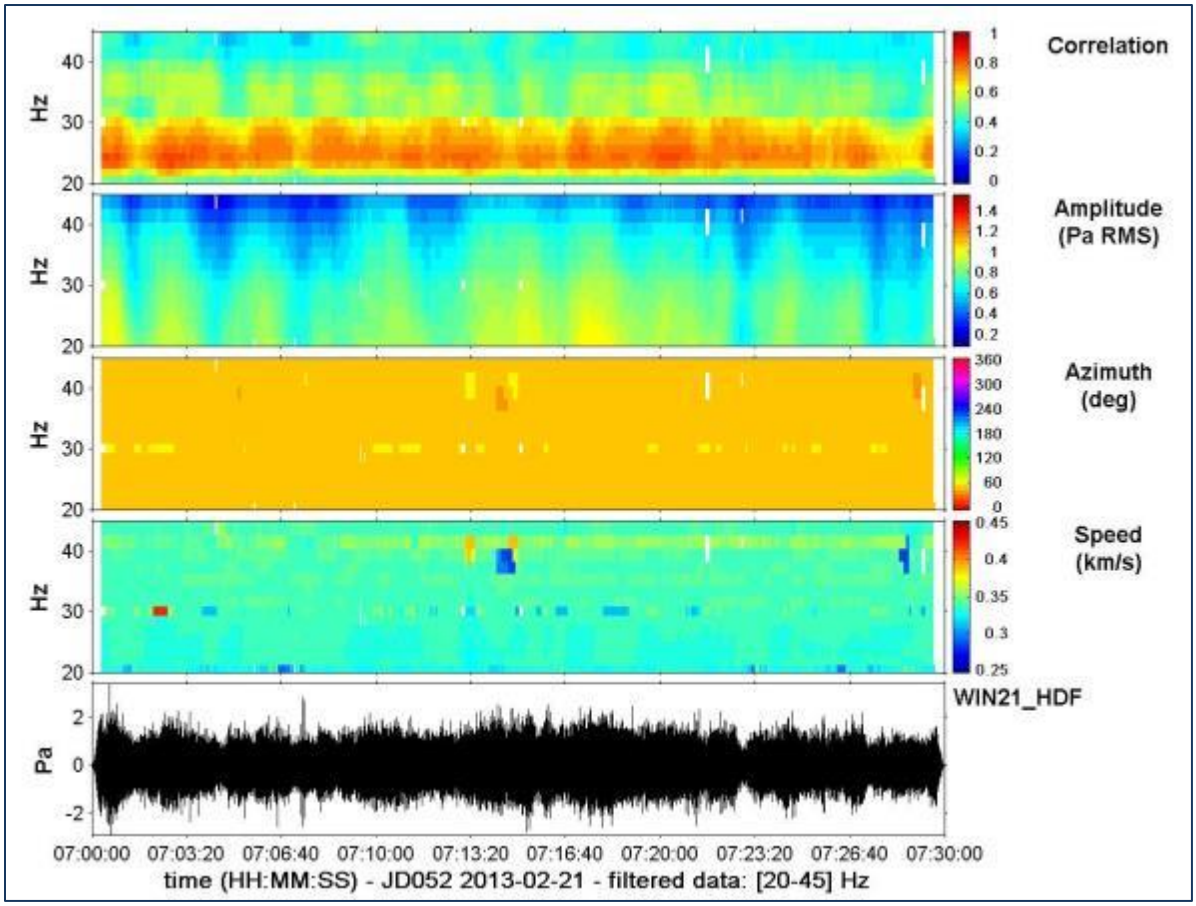


Figure 18: Signal recorded by Array 2 on February 21, 2013, 07:00:00 – 07:30:00 UT. The red colour in the top window is indicative of a coherent and correlated signal in the frequency range of 25- 30 Hz. A weaker signal is seen in the 35 Hz frequency band, but these two seem to be interconnected and may not represent the same type of signals seen at the Array 1. The apparent direction of signal arrival is 60 degrees (downtown Windsor).

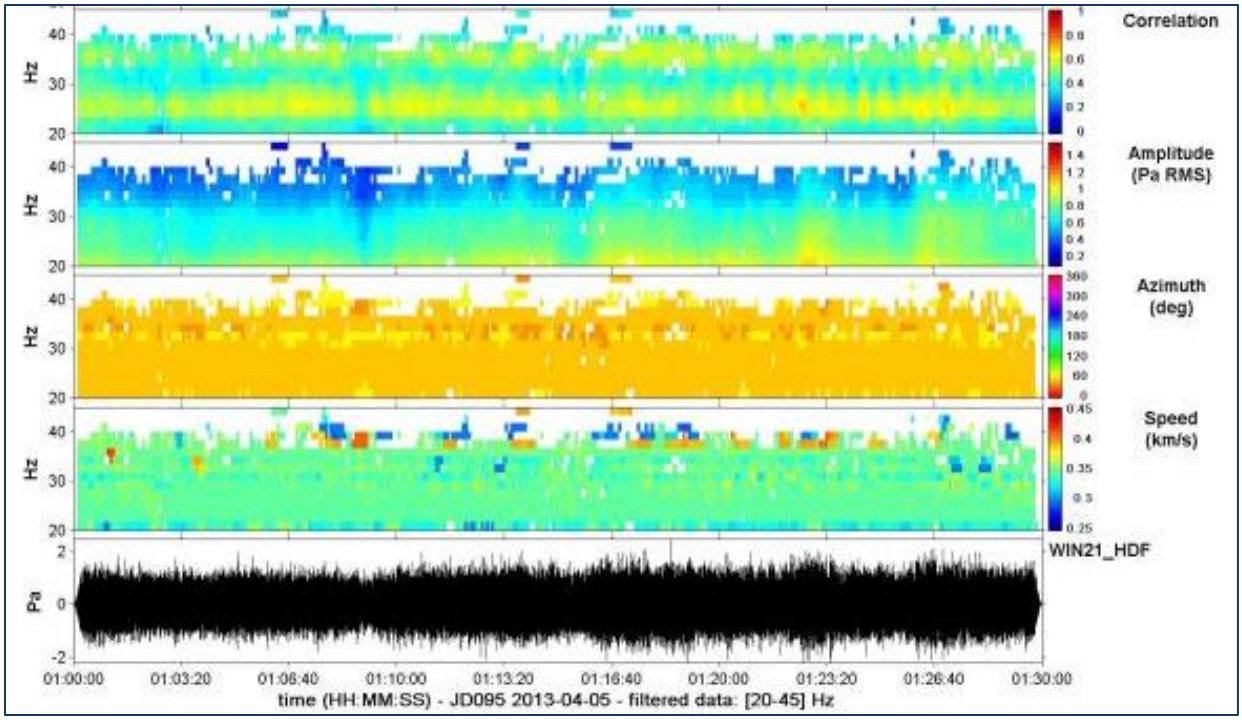


Figure 19: The signal as recorded by Array 2 on April 5, 2013, 01:00:00 – 01:30:00 UT. Both 25 Hz and 35 Hz signals are present and both seem to arrive from 60 degrees azimuth.

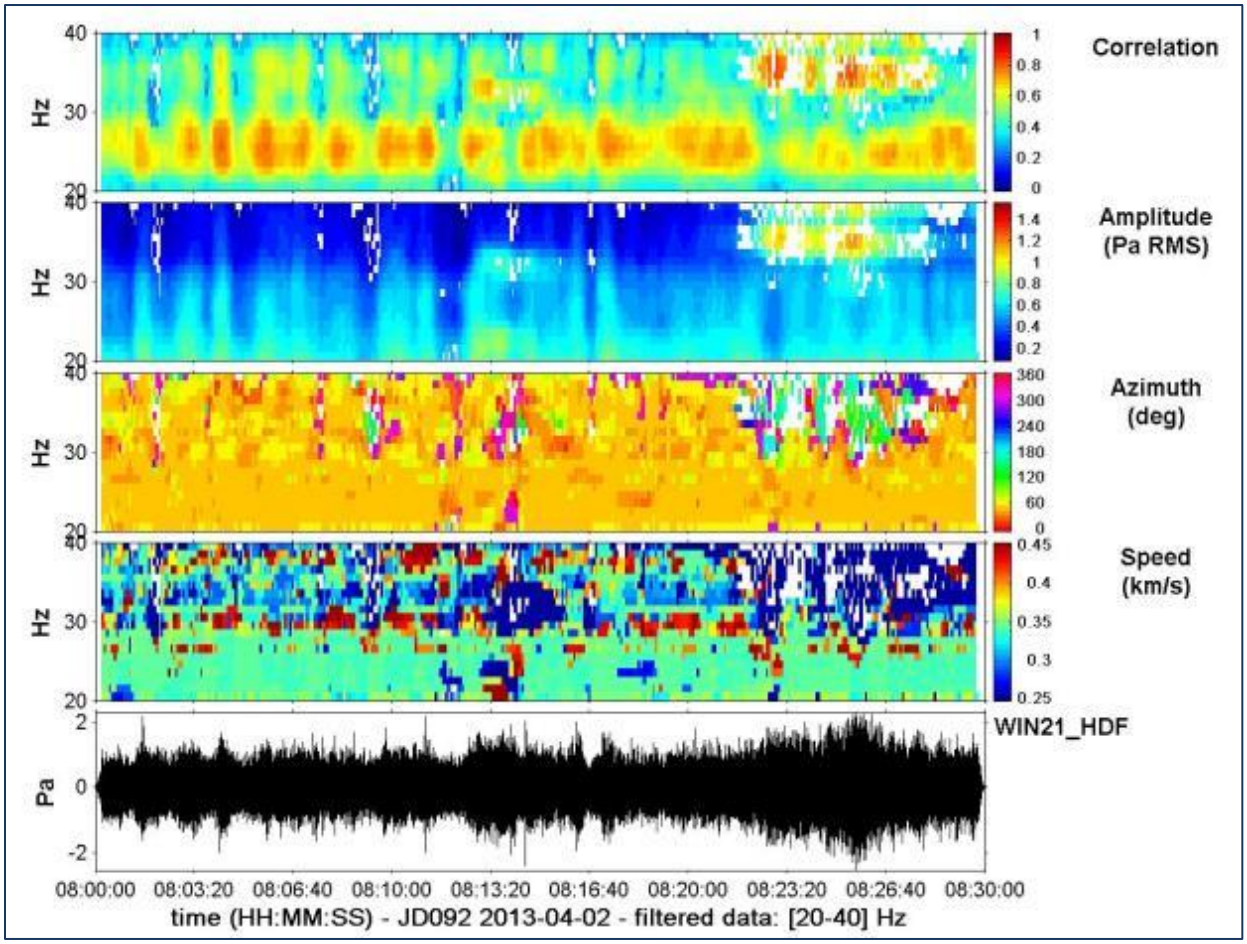


Figure 20: The PMCC results main window for April 2, 2013, from 08:00:00 – 08:30:00 UT at Array 2. The 25 Hz tone is noticeable and again comes from azimuth near 60 degrees.

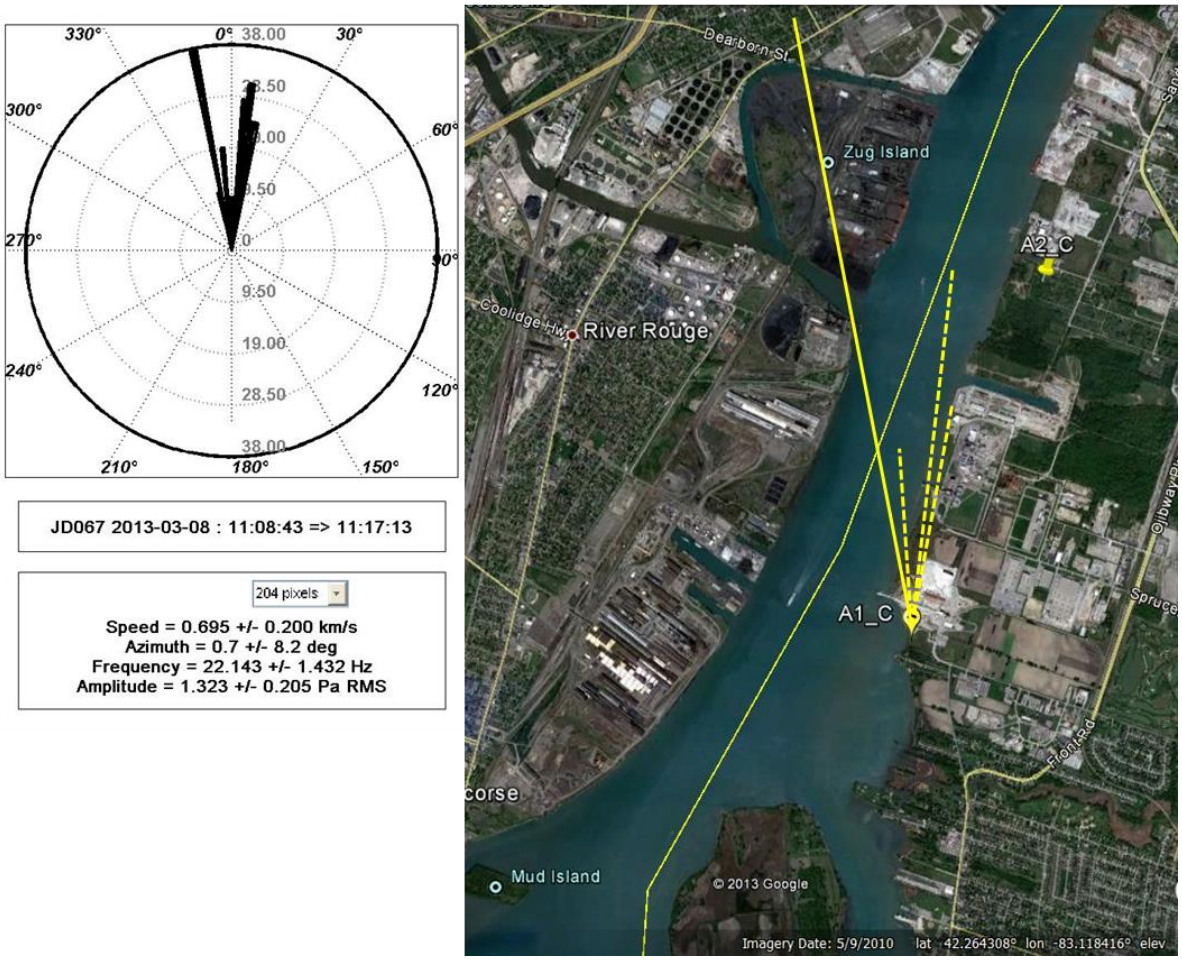


Figure 21: A rare instance of a signal at Array 1 coming from an azimuth other than ~270. In this case the signal on March 8 between 11:08-11:17 UT centred at 20-25 Hz does appear to come from nearly due North.

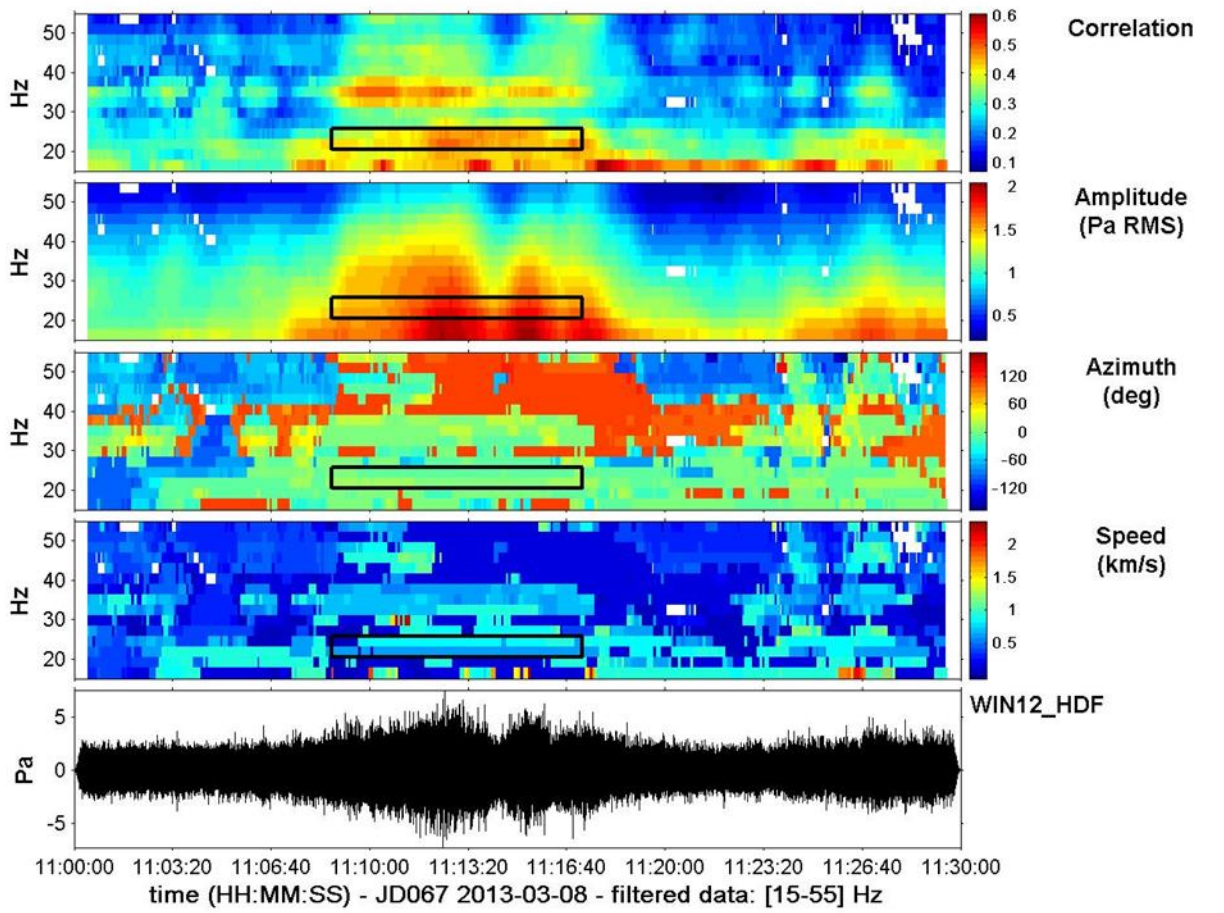


Figure 22: Array 1 results for March 8 from 11 - 11:30 UT. Note the strong correlated signal family from 11:10 - 11:17; this corresponds to the plot in Figure 21.

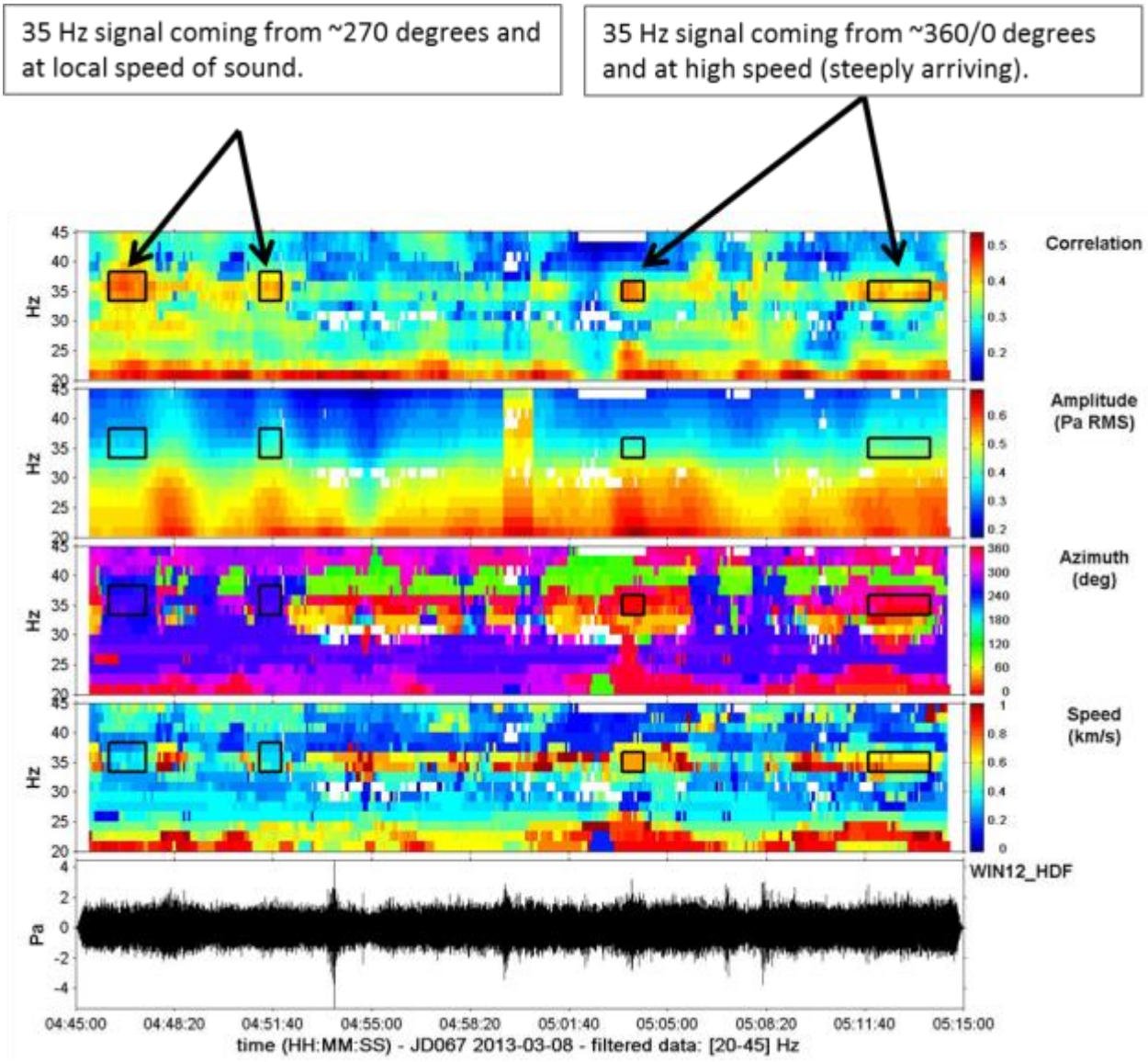


Figure 23: PMCC results for Array 1 on March 8, 2013.

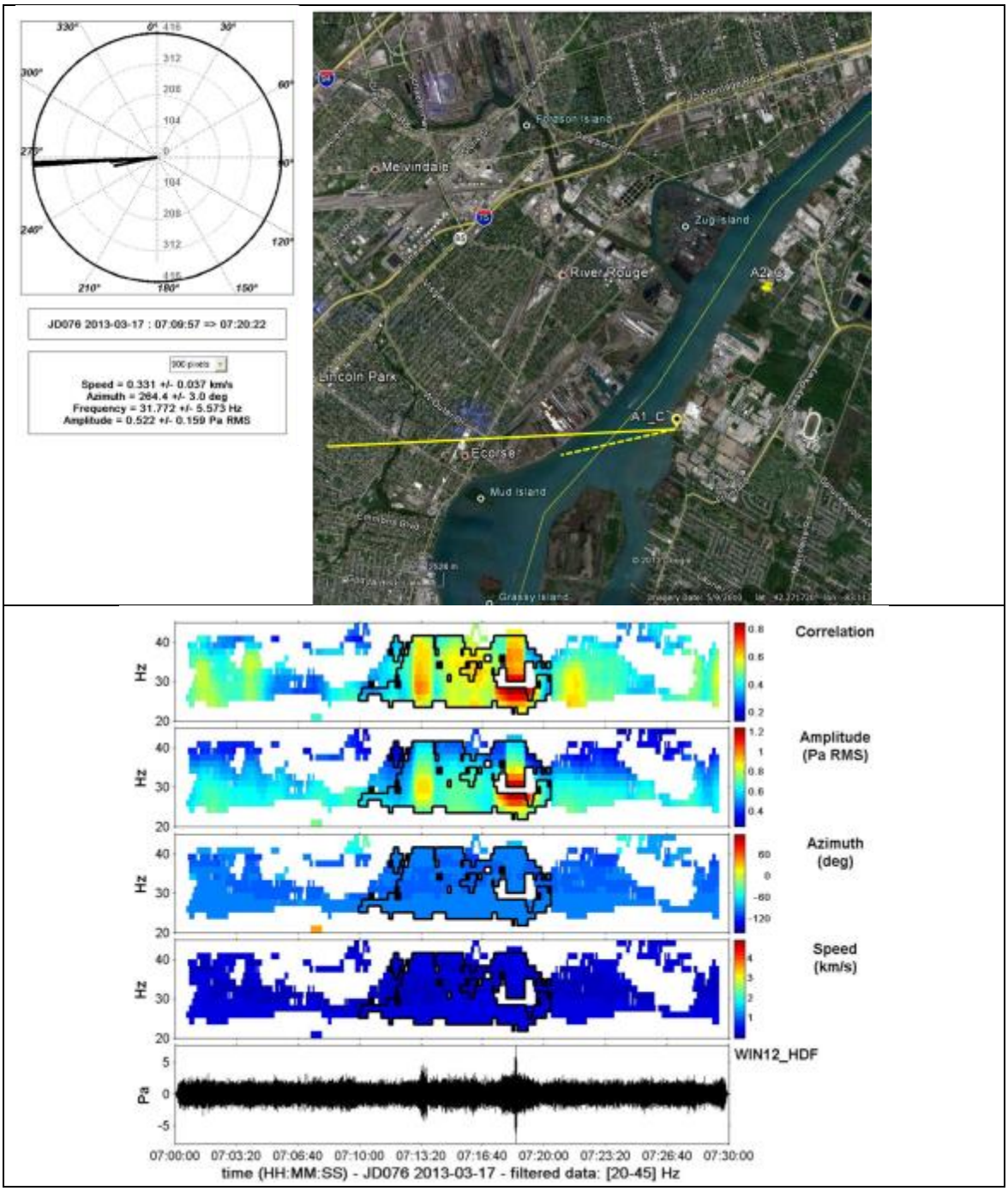


Figure 24: Top: Map and the polar plot showing the direction of signal arrival. The solid yellow line on the maps shows the approximate direction from which most of the signal energy is coming from. The dashed line represents another weaker signal from a similar direction.

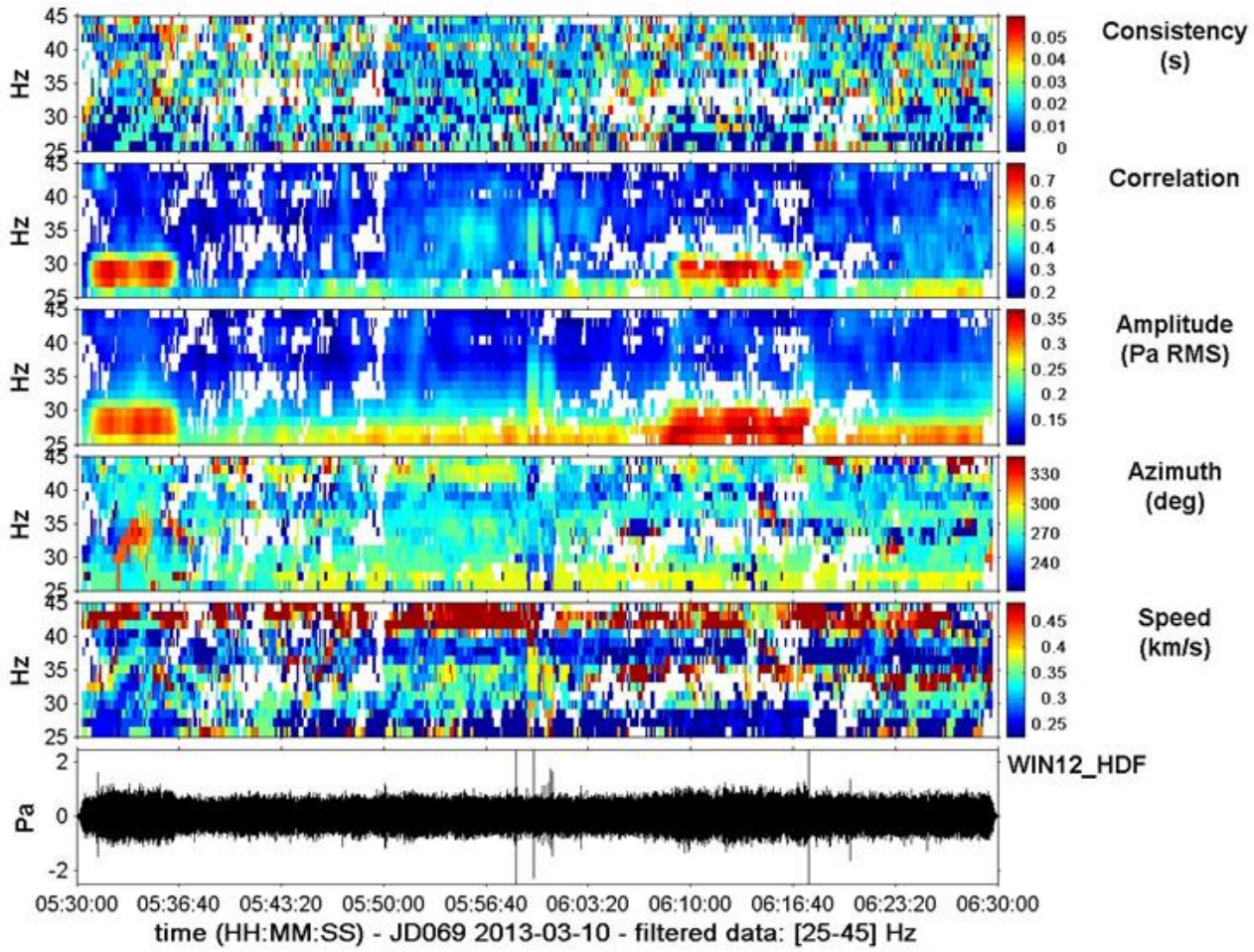


Figure 25: PMCC results for Array 1 on March 10, 2013.

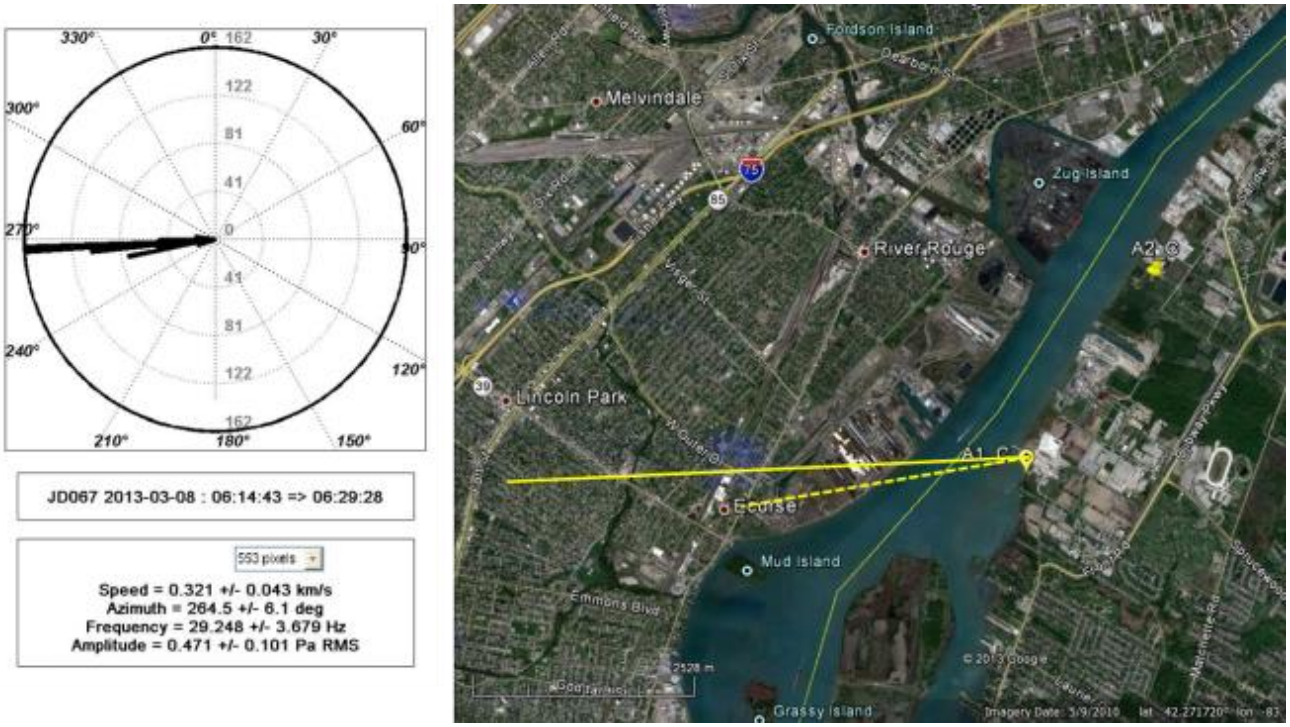


Figure 26: Directional bearing for the highly correlated 30 Hz signal family for Array 1 on March 8, 2013.

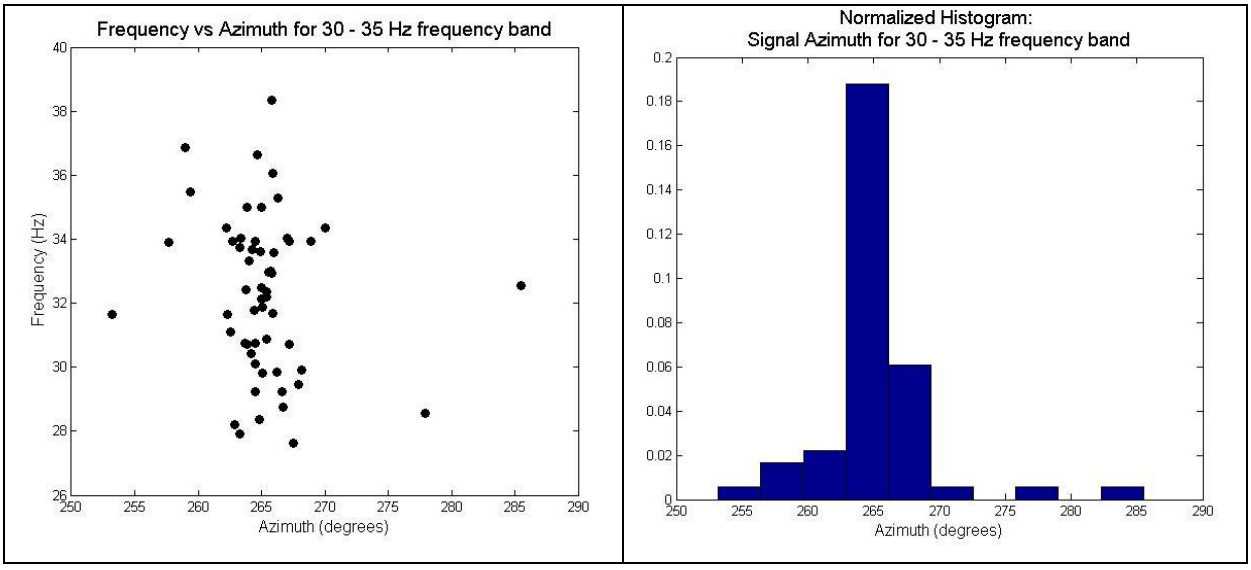


Figure 27: Left: Frequency vs. Azimuth for the arrivals coming from approximately 270 degrees. Right: Normalized histogram. The most prominent direction is 265±4 degrees based on 54 separate occurrences within the data sample analysed.

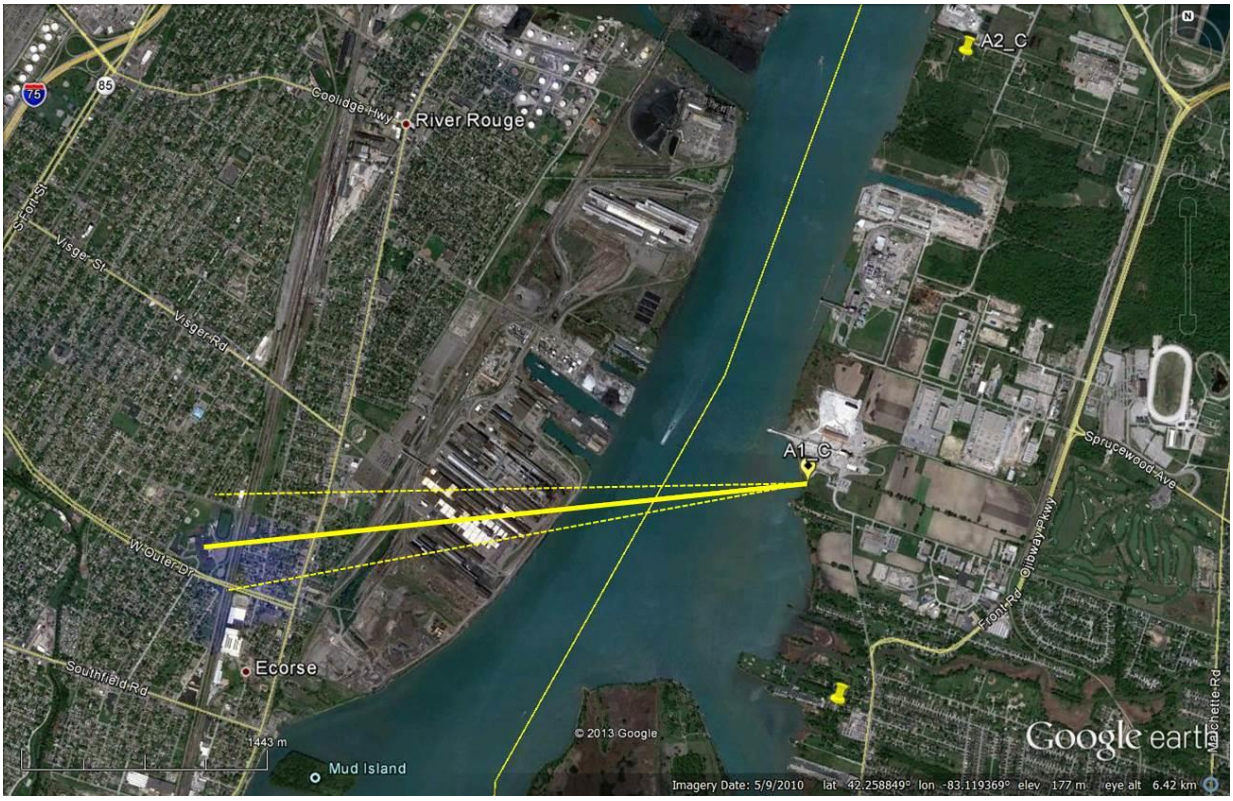


Figure 28: A map of the Array 1 showing the most probable direction of the Hum signal together with a bearing uncertainty (265 ± 4 degrees).

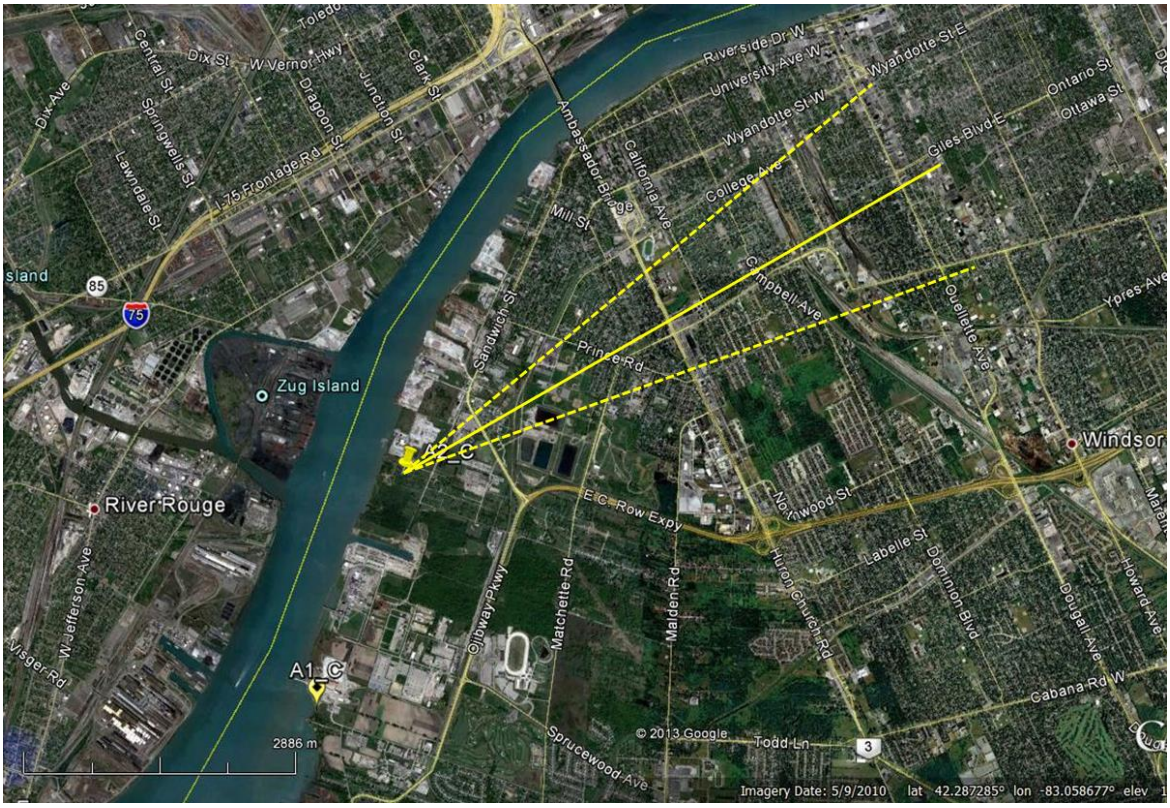


Figure 29: A map of the Array 2 showing the most probable direction of the Hum signal together with a bearing uncertainty (60 ± 10 degrees).

Appendix 1

Appendix 1a: Compilation of all reports collected via Western reporting system

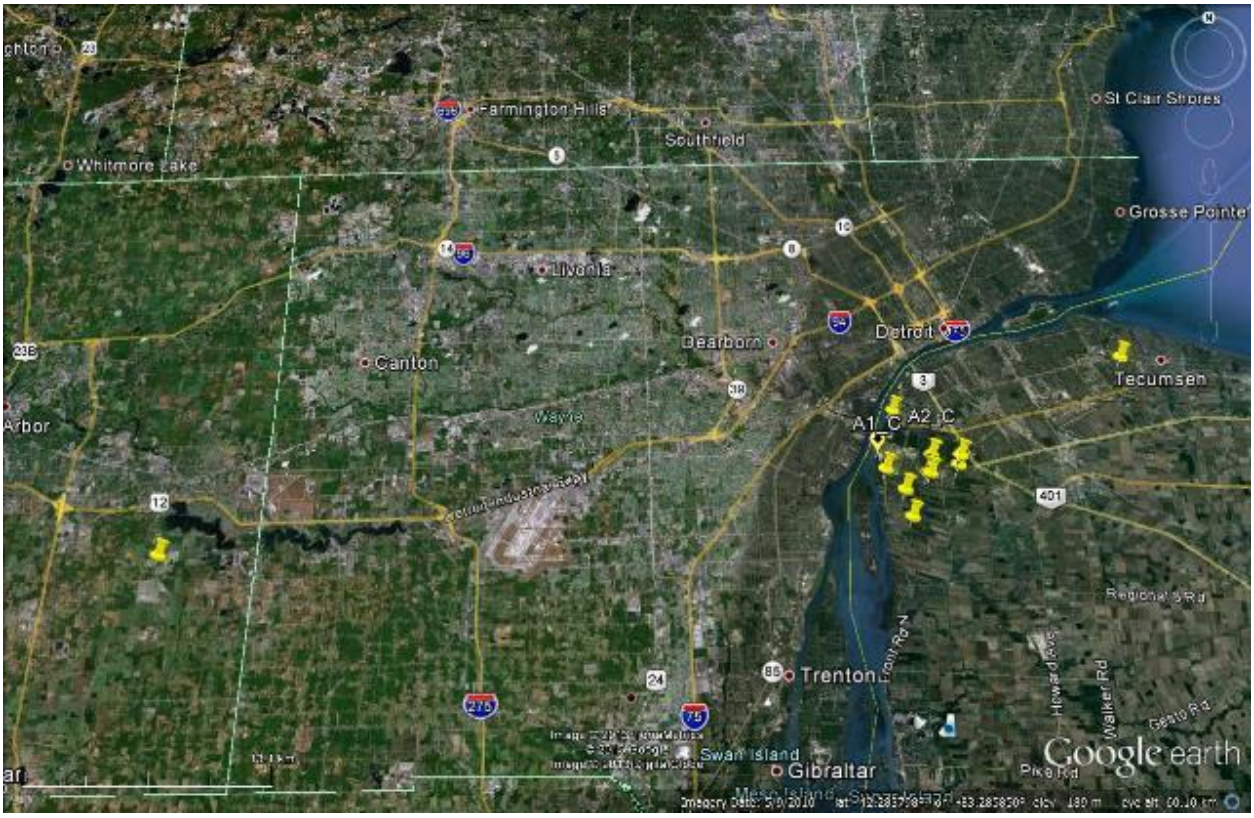


Figure A1-1: A regional map of the Windsor - La Salle - Detroit area showing the general region where public Hum reports were received during the study period. Note that almost all reports were to the South or South-East of both arrays.

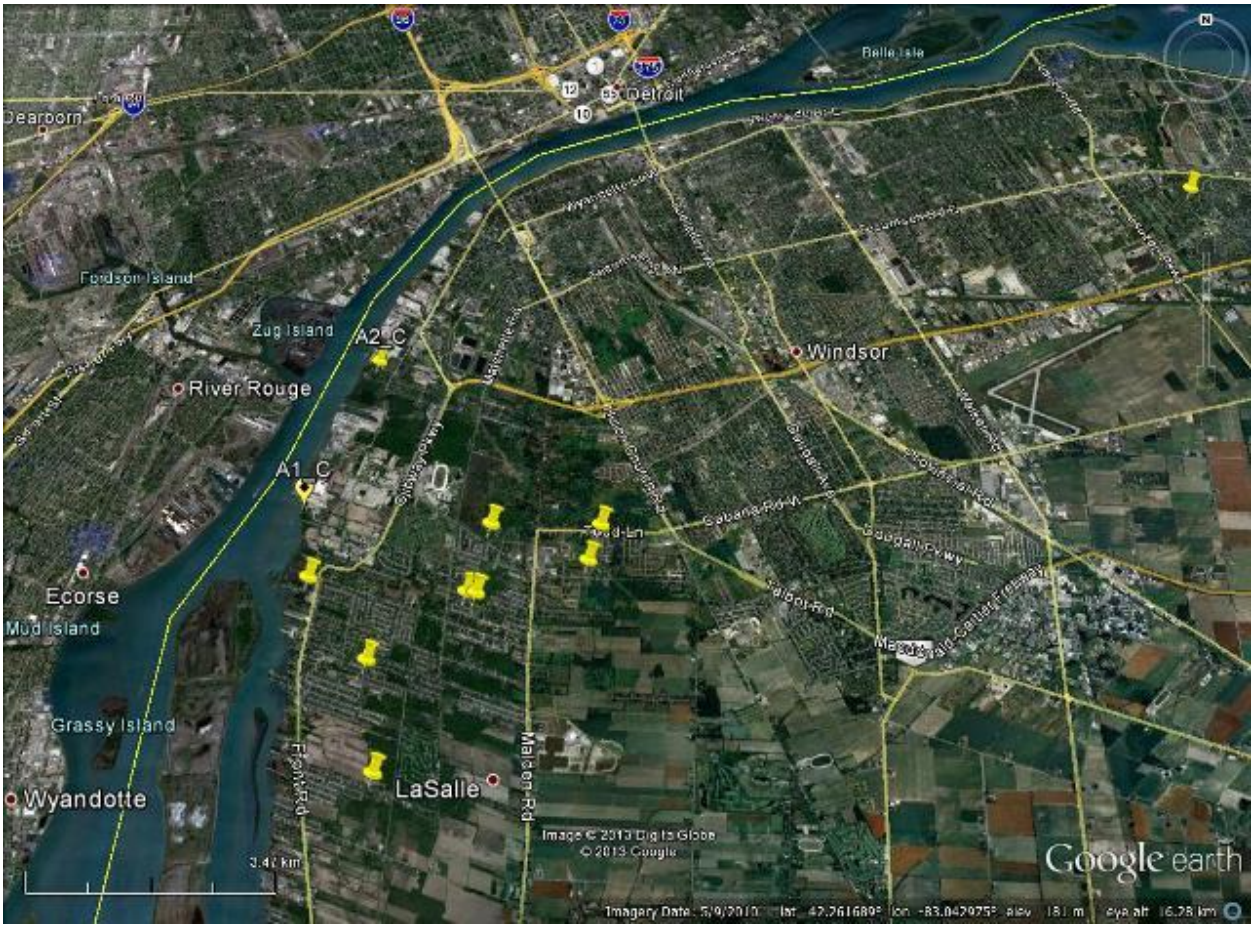


Figure A1-2: A close-up of the region near the Arrays showing approximate locations where Hum reports were received during the interval of the study.

Table 1: A compilation of all public Hum reports received by email or through the study dedicated website, including the date, time, duration and description.

Date	Local Time	Duration	Description
21-Feb-13	1:30 - 2:30	over 1 hr	Low-frequency hum
	00:45 - 01:05		mild hum and fans
	00:00 - 09:00	9 hrs	sounds like a truck engine idling
22-Feb-13	09-45 - 10:15		mild hum
	19:00 - 23:57		very loud hum, fans and horns
23-Feb-13	evening	all night	n/a
	00:35 - 01:04		very loud hum, horns and fans
	03:49 - 04:04		loud hum, a loud steam release at 4:01
	05:47 - 06:14		hum, fans and horns stil audible. Loud steam release
	08:29 - 09:50		a loud pulsing sound; volume going up and down
	08:29 - 14:30		hum, horns and fans
	23:00	all night	furnace noise all night
	all night	all night	hum, horns and fans; variable volume
	all night		heard and felt in the house; sounds like a distant thunder
24-Feb-13	11:37 - 11:56		loud steam release
25-Feb-13	23:13 - 23:37		hum and fans picking up in volume
	23:45		thunder-like rumble
26-Feb-13	evening	all night	continual furnace sounds or idling sounds
	05:13 - 05:35		a burst of noise; hum and fans
	09:36 - 09:47		hum, fans and horns, not very loud, but still audiuble
	11:03 - 11:26		loud fans
	22:41 - 22:59		hum and fans
27-Feb-13	18:30	--	medium level pulsing, rumbles and furnace noises
	00:43 - 00:59		hum and fans. Not very loud
	10:14 - 10:58		very loud hum, horns and fans.
	15:39 - 21:48		very loud hum, horns and fans, some mild rumbling
	18:30		rumbles and pulses
28-Feb-13	2:45	several hrs	loud rumbles and intermittent pulses
	02:52 - 05:49		hum, horns and fans with some rumbles
1-Mar-13	00:37 - 0046		slight hum
	09:32 - 09:46		slight hum
	21:00 - 23:47		hum, fans and horns
2-Mar-13	05:06 - 05:13		audible hum
	08:01 - 08:23		audible hum
	17:11		very heavy rumbling
3-Mar-13	4:30 - 6:30	2 hrs	Rumbles and vibrations felt and heard
	20:20	15 seconds	supersonic noise
	22:12	--	rumbling and vibrating
4-Mar-13	6:14 - 6:28	ends at 6:28	Rumbles and vibrations grow and intensify
	04:49 - 05:21		mild hum
	08:58 - 09:58		mild hum, volume is increasing, lots of air traffic
	12:53 - 13:50		hum and horns

Date	Local Time	Duration	Description
5-Mar-13	6:53	--	Slight rumbles
	01:59 - 08:36		very quiet
	8:25	meanwhile	loud furnace noise
	12:56 - 14:56	2 hrs	The noise alternated between pulsing and constant hum
	09:29 - 09:42		hum and fans started up
6-Mar-13	12:46	all night	Rumbles and vibrations being felt and heard and continue through the night
	01:16 - 01:34		quiet
	5:23	till morning	Rumbles and vibrations intensify and continue through early morning.
	06:00 - 06:18		quiet
	09:29 - 09:43		fans and some furnace noise
	10:30	--	a loud sonic noise
	16:02		rumbles
	19:34	--	furnace/ fan noises
	20:05 - 20:13		hum and truck idling sound, heavy air and ground traffic
	22:30	uncertain	thunder/rumble noise
7-Mar-13	4:23	--	very slight rumbles
	5:44 - 6:00	15 min	rumbles heard again but increasing in strength
	17:45 - 19:45	2 hrs	noticeable rumbles and pulses that can be heard and felt inside our home
	22:47 - 23:02	15 min	vibration booming rumble pressure
	22:30	all night	furnace/pulsing noise
8-Mar-13	23:30	all night and into morning	a very loud noise and it has been going every since
	00:06 - 06:27		fans, hum, horns;
	07:23 - 07:31		same as before, but now some grinding noise as well
	13:45		loud rumbles and fan noise
	18:49 - 23:29		ongoing hum, rumbles, fan noise
9-Mar-13	3:44		mild rumbles
	07:03 - 08:19		loud hum, horns and fans. Mild rumbling.
	all weekend	--	The entire weekend was filled with rumbles and very loud furnace type noise
	17:37 - 23-40		started mild, increaded to very loud. Hum, horns, fans and furnaces
10-Mar-13	17:45	--	Feeling steady, mild rumbles, cycling pulses inside out home and hearing constant train horns as well
	all weekend	--	
	00:06 - 02:57		loud hum, furnaces, horns, mild rumbles going up and down
	5:45 - 06:10		steady, mild rumbles, pulses inside house
	09:44 - 11:20		hum, furnaces, pulsing, with fluctuating volume
	18:00		rumbles
	18:31 - 23:41		hum, fans, furnace

Date	Local Time	Duration	Description
11-Mar-13	evening	all night	Annoying no break hum/furnace noise
	01:31 - 10:51		very loud hum
	6:00		rumbles
	18:40	--	barely audible
	16:02 20:26		very loud hum, horns, furnace, fans, very annoying (19:07 steam release)
13-Mar-13	3:45	--	Rumbles started to ramp up at 3:45am. Intensity increasing
	01:11 - 03:46		fans, furnace, horn noise. A few rumbles at 01:10
	12:06	ends at 5:45	began with a loud thud then the pulsing vibrating rumble began. This lasted appox. 15-20min. The low consistent rumble continued throughout the morning.
	15:29	--	barely noticable, We still hear the fan noises when we go outside, but it is low enough we are not hearing inside the house which we usually do
		--	LOUD and CLEAR furnace noise again
	23:17 - 23:30		hum
14-Mar-13	21:47	--	Major rumbles being heard outside and felt inside the house, the sound is like a roar in the open air.
	00:00 - 06:04		furnace/fans noise and hum
	06:01 - 06:04		loud banging/rumble, fans and furnace and hum
	22:34	subsided at 10:00 next day	a rumble that reverberated through my home. I could hear the whomping noise of the industrial fans and a drum like sound as well.
	0:00 - 4:40		very noisy, punching rumble reverberating the bed.
	11:27 - 11:29		mild furnace/fan, banging/rumble
	08:00 - 17:57		ongoing hum
	all night	--	noise/churning/furnace revved up and continued all night. some trains in the mix
	3:00	--	rumbling noise coming from the north west, corner Minto and Mcnabb
15-Mar-13	3:00	--	industrial fans and a drum like sound as well.
	00:00 - 9:36		furnace/fans and the hum, at time REALLY loud
	07:06 - 07:12		very loud, some distant rumbles
	08:00 - 08:25		extremely loud, some rumbles at 8:14
	6:23	--	The whole house is vbrating. Very loud rumbles.
	18:27		quiet
	20:30	5-10 min	huge rumbles
	20:37 - 20:49		fan/furnace, then the hum and idling sound like a prop plane around 20:46
	21:38 - 21:45		quiet
	23:00	all night until 7 am	It started booming around 11 and has not stopped in our area. It was like a pounding rumble that generated force. I'm not sure why it is sounding different and more intense, and there are the fan/furnace sounds and train horns. Around 3 am it was very intense straight through to 7 am

Date	Local Time	Duration	Description
16-Mar-13	0:11	5 hrs	At 12:11am hum started with vibration for about 10minutes then quieted to a low hum. Briefly the sound completely stop. Low hum continued thoughout morning. My observation ended around 5am
	16:52	--	loud furnace/fan/train horns
	14:00		quiet
	14:33	meanwhile	heard by Jackson park (Tecumseh Rd. E., N8X 3N5)
	22:32	1 hr	Hum began at 10:32Pm. It is a pulsing vibrating sound. The sound continues as I write this.
17-Mar-13	3:00	30 min	The hum sounded like an idling vehicle mixed with the sound of a valve sucking water (possibly) in
	00:22 - 6:54		fans and the hum, furnace n oise as well
	3:30	--	an intermittent rumble and the train horns are going. It's 5:12 am and the horns and mild rumbling is still going on
	19:23	4.5 hrs	oud Hum began. At 10:30pm pulsing booming started, it was loud enough to interfer with the sound from the TV. Pulsing continued into March 18, 2013
18-Mar-13	16:00	1 hr	Pulsing Hum
		--	QUIET
19-Mar-13	0:00	--	QUIET
	--	--	QUIET
	3:16	until morning	rumbling, vibrating, fan/furnace and train horns
	19:24	--	an/furnace very distinc
	23:10	--	an/furnace deep pressure type rumbling vibration
20-Mar-13	0:04	all night	Pulsing booming noise began then quieted to low hum thougout morning. Aproximately 7:00am Pulsing noise came back it continued until 8:30am. It may have continued beyond that but that was the end of my observation.
	3:10	--	very noisy with deep pressure type rumbling vibrations loud enough to be waken
	6:00	--	continues intermittent
	11:01	--	distant fan/furnace and the off train horn
	16:02	--	the fan/furnace sounds have increased and still hearing train noises
	18:10	30 min	mild rumbling and vibrating off and on for about a half hour. Train/furnace sounds can be heard
	21:09	--	train/furnace/fan
	22:30	--	QUIET
	23:23	--	low hum began
	23:53	--	hum is louder
		all night	Churning noise ALL NIGHT

Date	Local Time	Duration	Description
21-Mar-13	0:14	all night	Even louder the noise is really bothering my ears now, feels like I'm in a factory. The hum continued through the morning
	3:06	all night	We were kept awake most of the night with constant rumbling and vibrating. At 3:06 am until 6:30 it was very loud and consistent. Train horns went along with the above noise.
	5:00	--	Rumbling, similar to several large jets taking off in the distance with a faint hum (Diesel truck idling) accentuated with train whistle
	7:56	50 min	the sound of jet engines or turbines and many train whistles. Much louder outside than in coming from the direction of "The Island".
	7:30	30 min	very pronounce at around 7.30 to 8. A.M; Noise coming from the general direction of smoke stack/ zug island
	10:55	--	it is much quieter fan/furnace can be heard. It has been rumbling and vibrating, it started up around 11:00 am off and on and has been going all day.
	21:31	--	it is consistently rumbling and vibrating right now along with the train horns
	21:31	all night and morning	it has been rumbling and vibrating, loud fan/furnace noise and the train horns. It is 10:54 am and it is still going on. Very disturbing.
22-Mar-12	--	--	QUIET morning
	--	--	QUIET, currently experiencing nothing out my way in Lasalle. No furnace/ fan noise, rumbling, pulses
	19:30	1 hr	no rumbling, but fan/furnace can be heard
	21:00		QUIET
23-Mar-13		22:30	QUIET
	23:30	1 am next day	can feel a very low vibration and rumble still going on at 1:00 am
24-Mar-13	night/morning	--	QUIET
25-Mar-13		--	QUIET
	23:30		It is 11:30 pm and the rumbling and vibrating has started
26-Mar-13	2:50	--	awakened to pulses and mild rumbles at 2:30. I cannot fall asleep because it goes straight through me.
	10:21		rumbling
	14:19		rumbles and vibrations
	15:30		low level rumblings
	19:23		low level disturbance
	20:38	9 hrs	booming vibrating hum could hear over TV. Noise continued into morning
	22:00	70 min	Mild steady rumbles and pulses. Not too loud but discernible. I felt them in my ears and chest before I was even aware of the sound.
	23:30		low level disturbance
	--	--	continually churning heard inside the house on the west side. always hear it but with different degrees of loud (Mar 26). A little ear pressure at bed time.

Date	Local Time	Duration	Description
27-Mar-13	0:48	--	pulsing
	3:00		3 am rumbling noise coming from the north west, corner Minto and Mcnabb
	5:00		Mild steady rumbles and pulses heard inside the house most of the night; Also, outside very loud furnace/fan type noise off in the north west toward the river.
	6:00		lots of noise. A little stronger, just as steady. Lots of steady "boom" sounds
	15:55		Experiencing very loud, steady cycling 2 second pulses here in Lasalle!, Sounds like "vroom vroom vroom."
	20:15		The furnace noise, jet plane noise and the train whistles are all in full swing
	20:38	9 hrs	booming vibrating hum could hear over TV. Noise continued into morning
	22:30		same old noise, churning/furnace noise...non stop
	23:00		rumbling and vibrating
	22:00 - 23:00		quiet
28-Mar-13	18:00		quiet
	0:00	all night	rumbling and virating
29-Mar-13	0:25		low rumbles and pulses inside our home for the last several hours
	0:35		low Hum began a little after 12:35am
	1:00		grew louder
	3:00		Rumbles, high pitched noise, ears hissing, dogs crying and acting all weird, vibrations and constant whomp whomp whomp
	4:30		quiet
	4:40		hum began again
	7:30		Major, ongoing rumbles and pulses happening here in Lasalle. It's very loud outside and inside the house; Strong, deep heavy cycling pluses
	11:00		hum intermittent
	12:29		quiet at the moment
	16:38		rumbling and vibrating, which can be felt and heard
	17:00		quiet
	17:11		ery low level rumbling, vibrating and pulsing, but you can feel and hear it.
	17:53		quiet
	18:15	5 hrs	the rumbling, vibrating pulsing has started up again
	23:00		Furnace and fan noise to the north west and steady mild rumbles
	23:30		High pitched pulsing and churning this evening, very annoying and droning
	9-12:14		quiet

Date	Local Time	Duration	Description
30-Mar-13	1:15		rumbling and the jet engine noise going pretty good
	11:49 - 17:06		quiet (heard from others otherwise, but this location is quiet)
	morning		quiet
	20:41 - 23:01		loud engine type noise, mild rumbles and horns
	20:00 - 20:30		It's crazy loud right now: Rumbles, pulses, furnace and train noise. Steady and getting worse. Feeling and hearing it inside our home and outside as well.
31-Mar-13	0:00	6 hrs	the rumbling and vibrating along with furnace/fan noises started and went off and on all night
	00:00 - 8:00		the noise has been non stop since 8 pm last night
	00:30 - 1:00		Loud rumbles heard inside the house. Loud, streaming furnace noise off to the north west as usual.
	00:32 - 07:48		loud furnace/fans, engine noise and train horns, occasional rumble
	2:20		churning and train whistles all night long, since last evening.
	2:30	3 hrs	Awaken by hum at 2:30am
	5:57	30 min	vibrated awake
	6:00 - 8:00	2 hrs	furnace sounds and some pulsing
	9:20		It is crazy noisy right now. Lots of train whistles, rumbles and jet engine noise.
	10:37		the fan/furnace noise is being heard right now
	14:00		fairly quiet fan/furnace noise is being hear
	16:53		fan/furnace noise and train horns are pretty noisy right now, intermittent rumbling vibrations
	21:00	45 min	the rumbling and vibrating has started
	22:46 - 23:37		mild engine rumbling, hum, horns, fans/furnaces
01-Apr-13	17:45 - 18:15	30 min	vibrating and rumbling low level
	00:12 - 4:20		mild hum, fans/furnace volume changes, steam releases
	20:04 - 21:04	1 hr	rumbling and vibrating
	00:00 - 7:32		30-40 Hz, peaking at 34 Hz
02-Apr-13			
	3:00	3 hrs	Rumbles and cycling pulses here in Lasalle felt inside the house at about 1-2 second intervals at 3:00 am; getting louder and more intense.
	3:00	2 hrs	Woken up by rumbling noise heard this morning between 3 and 5 am. (April 3) it appeared the noise was coming from the north west.
	21:00	all night	The rumbling and vibrating started last night at 9:00 pm and continued off and on all night
	20:15 - 22:56		mild furnace fans, idling engine noise

Date	Local Time	Duration	Description
03-Apr-13	3:00	4 hrs	rumbling and vibrating along with continuous train horns
	6:00	30 min	Hearing and feeling steady booming/rumbles every second or so inside our home. Noteworthy at the time above but has been going on for a few hours.
	7:46	20 s	burst of vibrations
	10:15		quiet
	17:35		furnace noise
	20:00		quiet
	05:30 - 08:17		mild furnace/fan noise
	09:24 - 09:29		engine idling on and off
	14:34 - 16:51		quiet
	morning		low vibrations inside not so much outside. Ears are slightly ringing.
04-Apr-13	1:30		it was after midnight and still on at about 1:30 a.m., the hum seems to hit the house on the front (West, NW sides) and be not as noticeable in my bedroom, which faces E.
	8:12		The rumbling is present as is the jet engine noise and hissing in my ears.
	10:00		continual non stop low vibrations felt inside my home from the west..ears ring
	19:00	3 hrs	rumbling; Felt a low resonating base throughout the house. I also heard a new sound like maybe a propeller going in a stacata sort of way. There also was a sound of a loud furnace
	20:10	1.5 hrs	rumbles and vibrations
	22:00		loud air, can't really explain any better.pulsing, rumbling, furnace. churning etc
05-Apr-13	1:00		Humming and droning loudly out there tonight and train whistles are loud and ongoing
	1:00		Major rumbles and cycling pulses being felt inside our home all April 4 evening but particularly bad at this time (1:00 am April 5). Very loud. We can feel them go through us.
	1:00		The hum seemed extra bad, pretty much instantly felt nauseated. (It is like feeling car sick when it hits you).
	11:00	12 hrs	quet
	17:00		quiet
	23:00		very low hum
	02:15 - 02:21		hum, fans, furnace, steam release
	23:55 - 23:59		hum, fans, furnace, steam release
	all night		he rumbling and vibrating continued through the night and train horns chimed in at 4:30 am
07-Apr-13	3:00	2 hrs	Rumbles/pulses being heard and felt inside the home.
	00:42 - 12:15		very loud hum
	19:00 - 20:00	all night	heavy rumbling
	22:00		a low distant rumble vibration that can barely be felt but it is there. It is 10:00pm and the same low level rumbling vibration is there
08-Apr-13	morning		walked outside and churning loudly with train noise but the noise is more south/west than usual
	3:00	3 hrs	loud train horns and a engine drone

Appendix 1b: Global summary of the answers to all Hum report questions

The comprehensive follow-up survey consisted of the following questions:

1. Do these two types of sound (furnace sound/hum and pulsing) usually come together?
2. Is one more prominent than the other?
3. If they come separately, which one is more likely to come by itself?
4. Which sound is longer lasting (e.g. persists for hours)?
5. How far apart are the pulses usually? Do they always follow the same pattern (time between the pulses)?
6. Do pulses come at random times, or is there any particular pattern (times at which they occur, for example nights)? What about the furnace sound?
7. There are reports of vibrations – are they associated with one of those two types of sound, and if yes, which one?
8. Do the vibrations ever come on their own?
9. Are the vibrations felt in the walls at all? What about the ground? Indoors or outdoors?
10. How are the vibrations felt physically?
11. When is the Hum most prominent? Is there any specific pattern?
12. What is the direction of the Hum? Is it always the same?
13. Does it ever feel like it comes from the ground?
14. Did you notice anything different during the period of Feb 20 – Apr 7, 2013? For example, less or more vibrations, less or more pulsing, etc. Is this time period representative of the typical Hum presence?

1. Do these two types of sound (furnace and pulsing) usually come together?

8 people answered YES	12 people answered NO

2. Is one more prominent than the other?

17 people answered YES	1 person answered NO
2 answers were INAPPLICABLE	

3. If they come separately, which one is more likely to come by itself?

8 people answered PULSING	10 person answered FURNACE
2 answer was INAPPLICABLE	

4. Which sound is longer lasting (e.g. persists for hours)?

8 people answered PULSING	12 person answered FURNACE

5. How far apart are the pulses usually? Do they always follow the same pattern (time between the pulses)?

Distance between pulses:

9 people answered SECONDS (>5 SECONDS)	3 person answered MINUTES (<1 MINUTE)
2 people answered RANDOM	2 people answered NOT SURE
1 person answered NO INTERVAL	1 answer was INAPPLICABLE

Same pattern:

8 people answered YES	10 people answered NO
2 answers were INAPPLICABLE	

6. Do pulses come at random times, or is there any particular pattern (times at which they occur, for example nights)? What about the furnace sound?

Random?(PULSES):

13 people answered YES	5 people answered NO
2 answers were INAPPLICABLE	

Type of pattern (if applicable) (PULSES):

3 people answered EVENING/NIGHT	2 people answered MORNINGS
1 people answered CLOUDY NIGHTS	

Random?(FURNACE):

10 people answered YES	5 people answered NO
5 answers were INAPPLICABLE	

Type of pattern (if applicable) (FURNACE):

2 people answered EVENING/NIGHT	2 people answered MORNINGS
1 answer was INAPPLICABLE	

7. There are reports of vibrations – are they associated with one of those two types of sound, and if yes, which one?

Are they associated? :

16 people answered YES	1 person answered NO
3 answers were INAPPLICABLE	

Which one? :

11 people answered PULSES	4 people answered NO
1 answer was INAPPLICABLE	

8. Do the vibrations ever come on their own?

7 people answered YES	10 people answered NO
3 answers were INAPPLICABLE	

9. Are the vibrations felt in the walls at all? What about the ground? Indoors or outdoors?

12 people answered WALLS	8 people answered OUTDOORS
7 people answered GROUND	3 people answered WINDOWS

10. Are the vibrations felt physically?

15 people answered YES	1 person answered NO
4 answers were INAPPLICABLE	

11. When is the Hum most prominent? Is there any specific pattern?

7 people answered EVENINGS	4 people answered CLOUDY/BAD WEATHER
3 people answered MORNINGS	3 people answered NO PATTERN
4 answers were INAPPLICABLE	

12. What is the direction of the Hum? Is it always the same?

Direction:

5 people answered WEST	1 person answered NORTH
8 people answered NORTHWEST	1 person DOESN'T KNOW
5 answers were INAPPLICABLE	

Constant direction? :

18 people answered YES	2 answers were INAPPLICABLE

13. Does it ever feel like it comes from the ground?

7 people answered YES	10 people answered NO
3 answers were INAPPLICABLE	

14. Did you notice anything different during the period of Feb 20 – Apr 7, 2013? For example, less or more vibrations, less or more pulsing, etc. Is this time period representative of the typical Hum presence?

6 people answered LESS VIBRATIONS	3 person answered NO
3 people DON'T KNOW	8 answers were INAPPLICABLE

Appendix 2

Appendix 2a: Array 1 (Windsor Salt) - PMCC results for select dates and time segments corresponding to intervals when public reports indicate some Hum activity

20130308

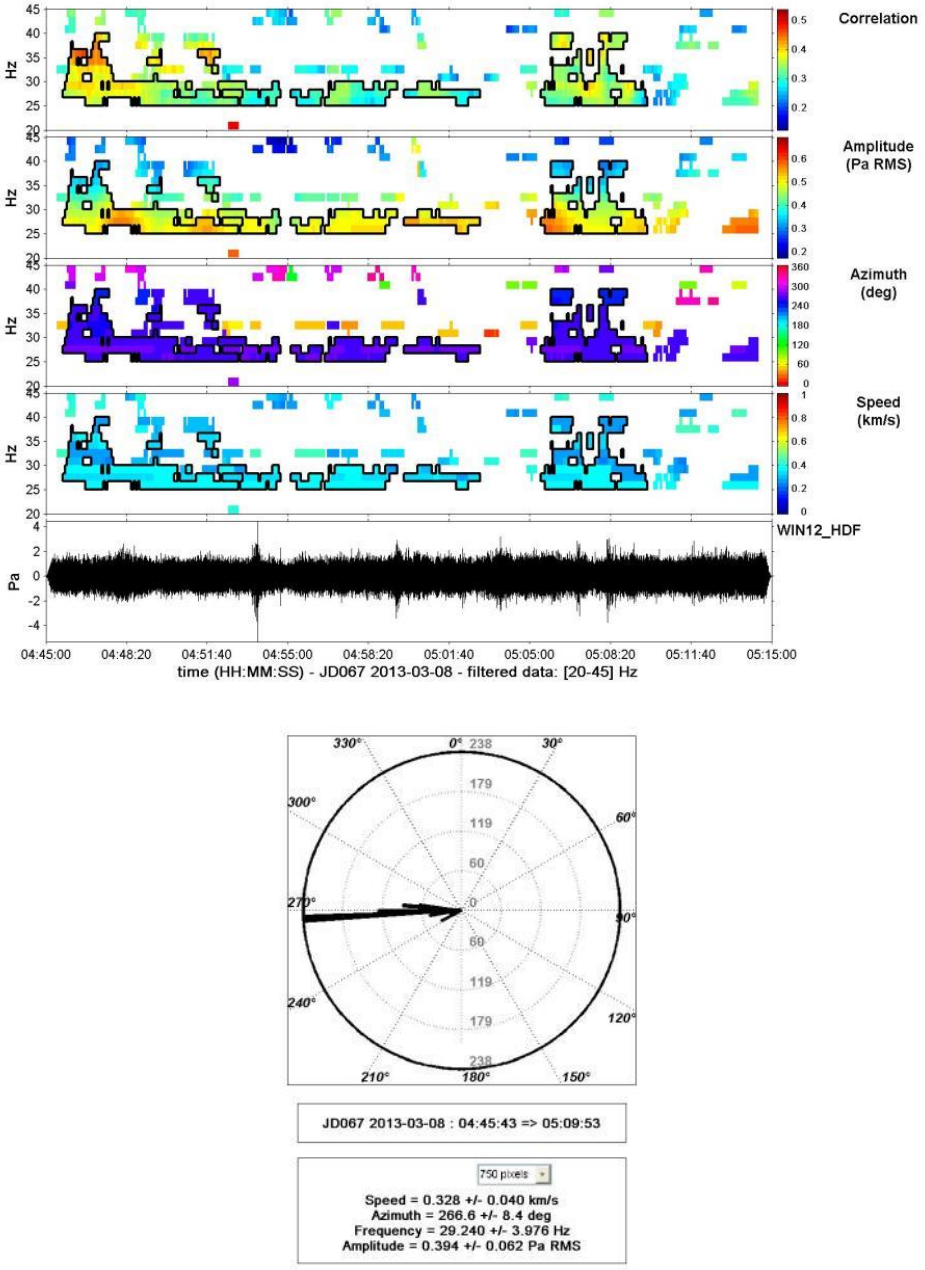
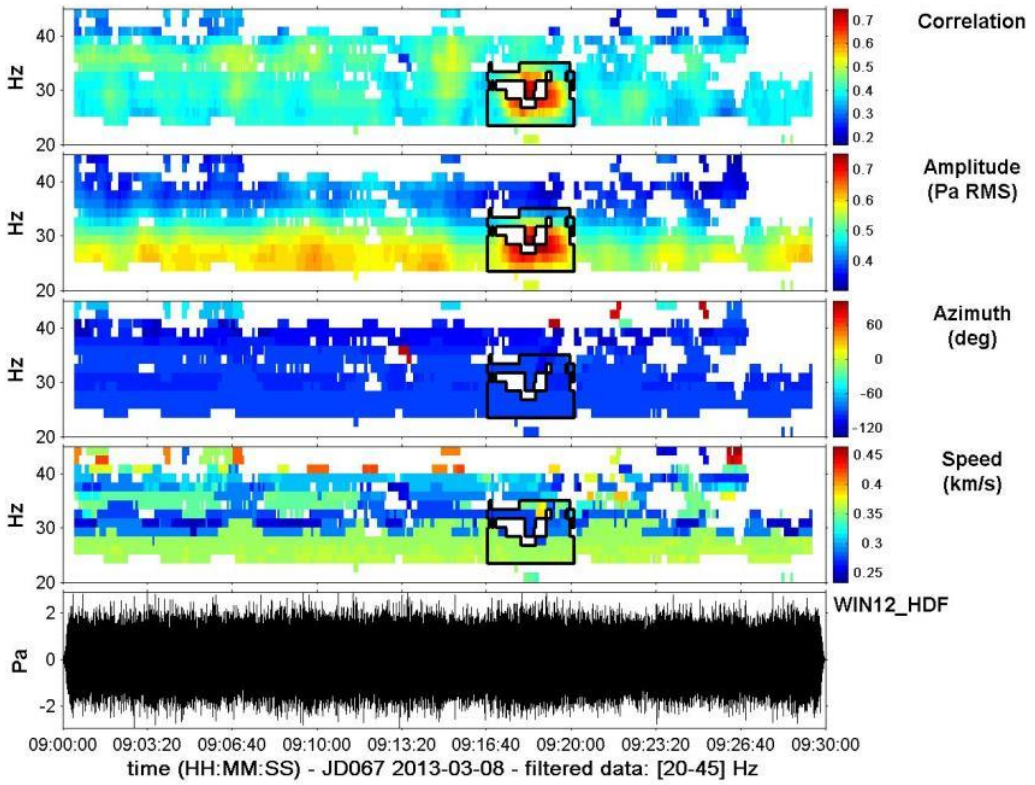
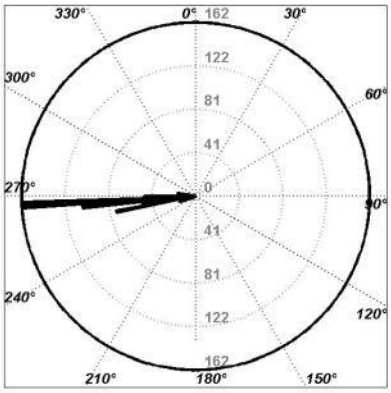


Figure A2-1



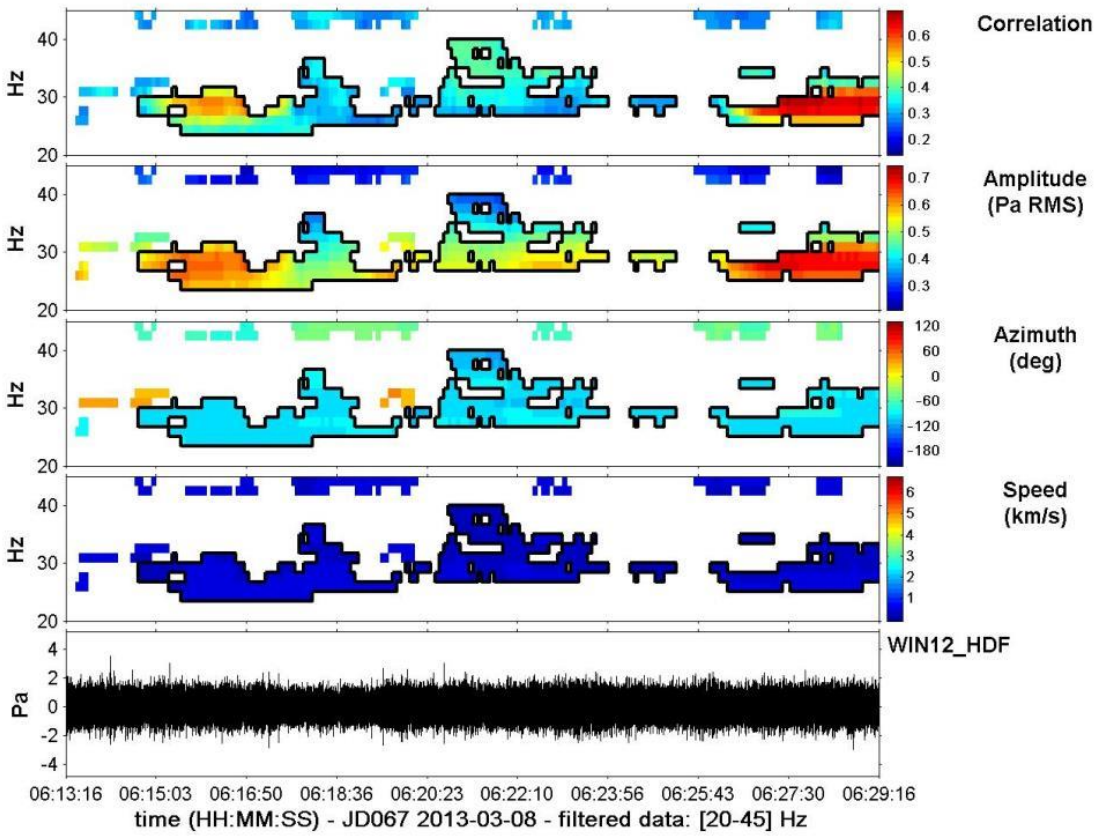


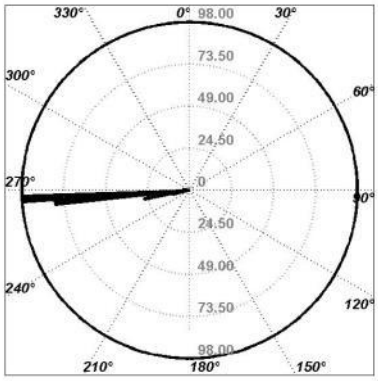
JD067 2013-03-08 : 06:14:43 => 06:29:28

553 pixels

Speed = 0.321 +/- 0.043 km/s
Azimuth = 264.5 +/- 6.1 deg
Frequency = 29.248 +/- 3.679 Hz
Amplitude = 0.471 +/- 0.101 Pa RMS

Figure A2-2



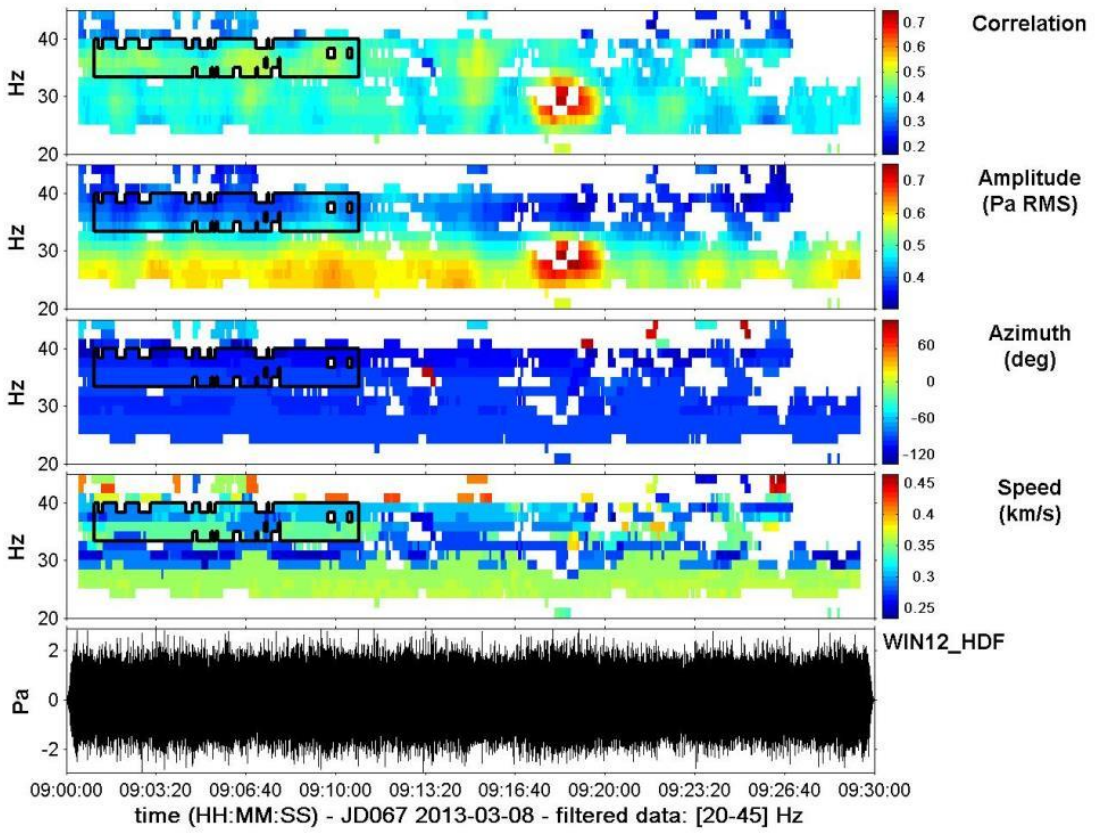


JD067 2013-03-08 : 09:16:43 => 09:20:08

222 pixels

Speed = 0.331 +/- 0.040 km/s
Azimuth = 264.8 +/- 3.7 deg
Frequency = 28.374 +/- 3.686 Hz
Amplitude = 0.547 +/- 0.096 Pa RMS

Figure A2-3


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
09:00:00 09:03:20 09:06:40 09:10:00 09:13:20 09:16:40 09:20:00 09:23:20 09:26:40 09:30:00
time (HH:MM:SS) - JD067 2013-03-08 - filtered data: [20-45] Hz

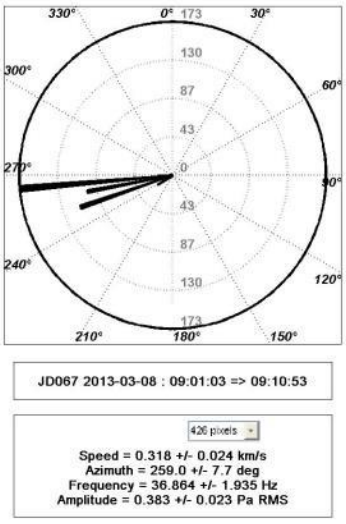
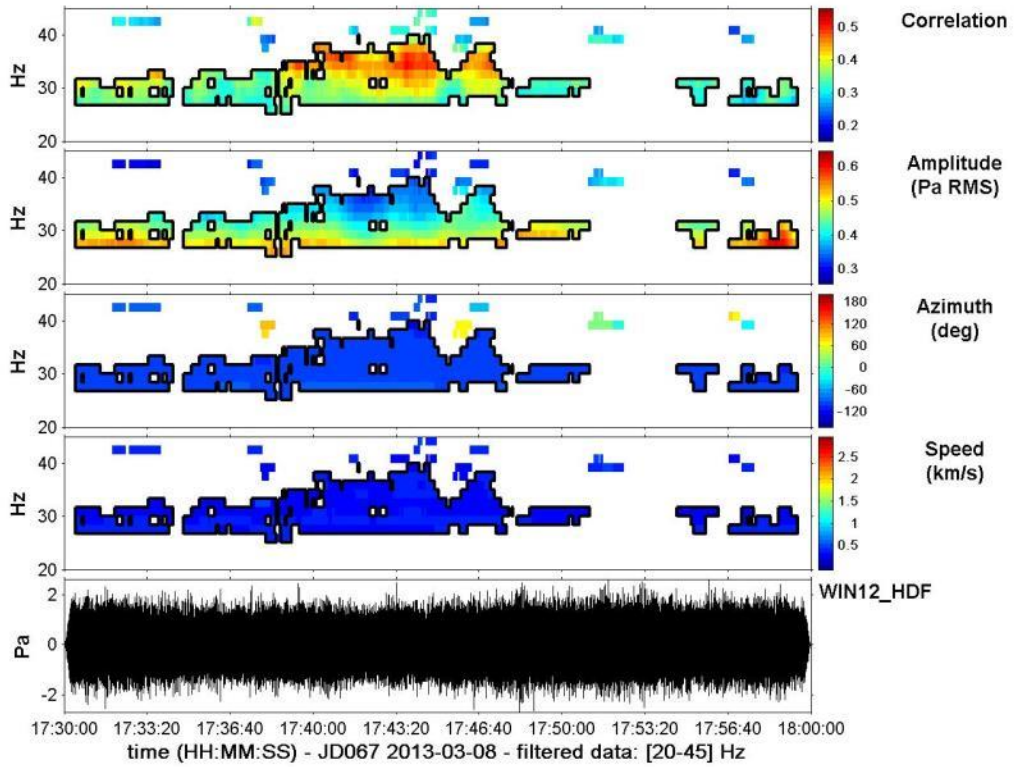
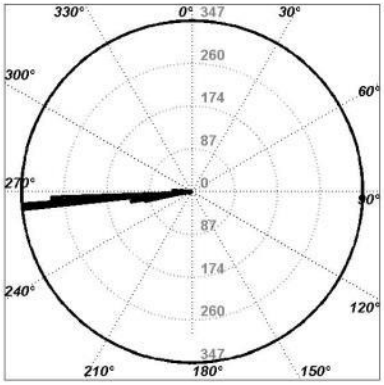

JD067 2013-03-08 : 09:01:03 => 09:10:53
426 pixels
Speed = 0.318 +/- 0.024 km/s
Azimuth = 259.0 +/- 7.7 deg
Frequency = 36.864 +/- 1.935 Hz
Amplitude = 0.383 +/- 0.023 Pa RMS

Figure A2-4





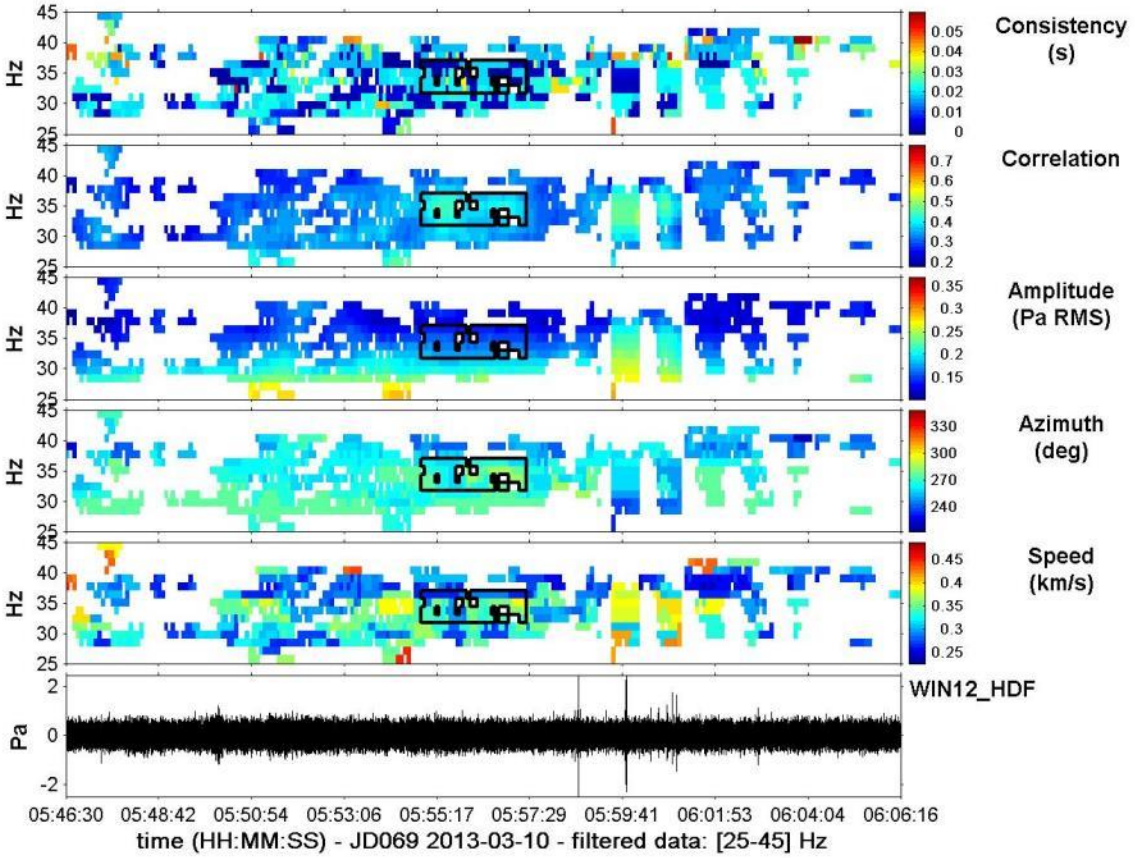
JD067 2013-03-08 : 17:30:28 => 17:59:27

1038 pix...

Speed = 0.321 +/- 0.049 km/s
Azimuth = 264.5 +/- 5.2 deg
Frequency = 30.737 +/- 3.095 Hz
Amplitude = 0.414 +/- 0.059 Pa RMS

Figure A2-5

20130310



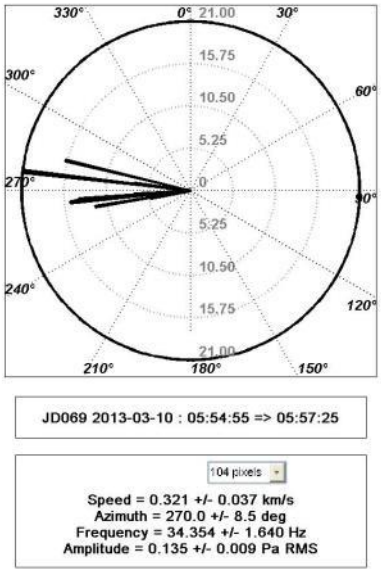
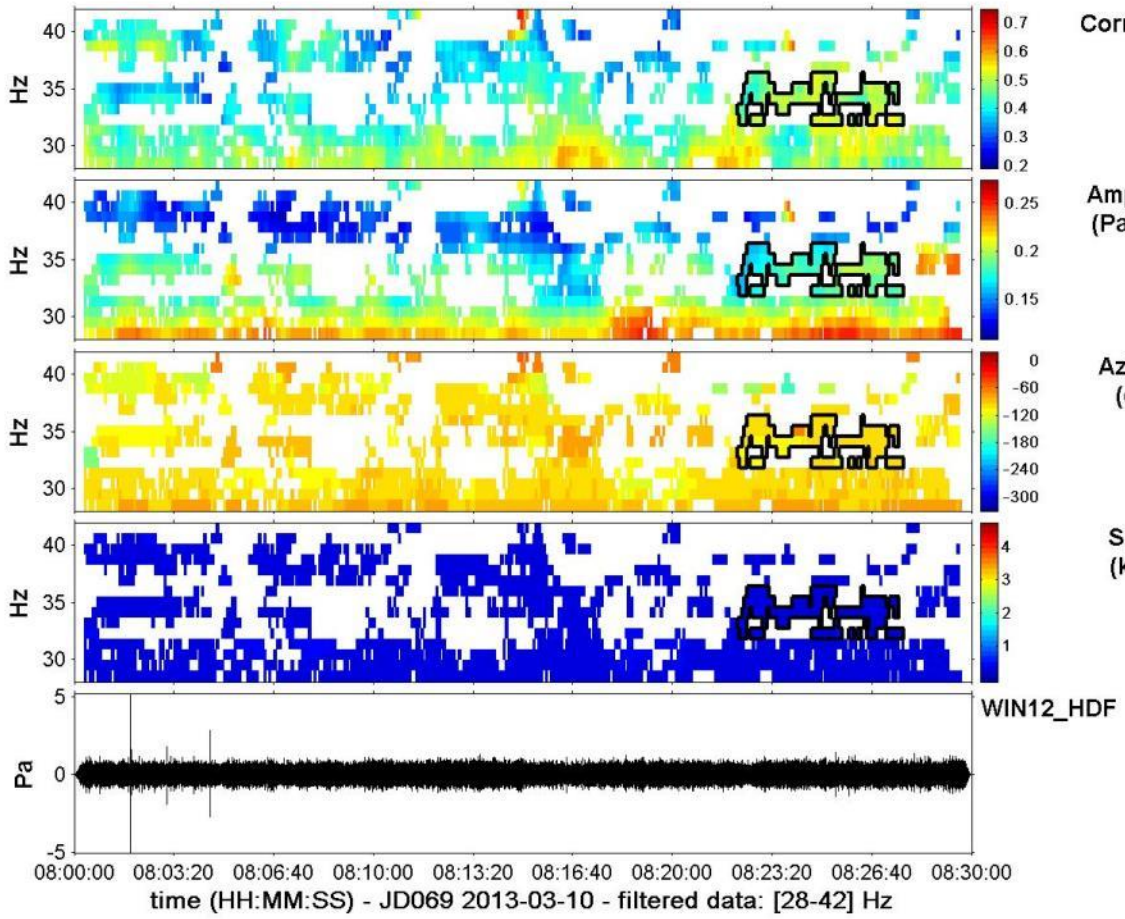


Figure A2-6


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
time (HH:MM:SS) - JD069 2013-03-10 - filtered data: [28-42] Hz

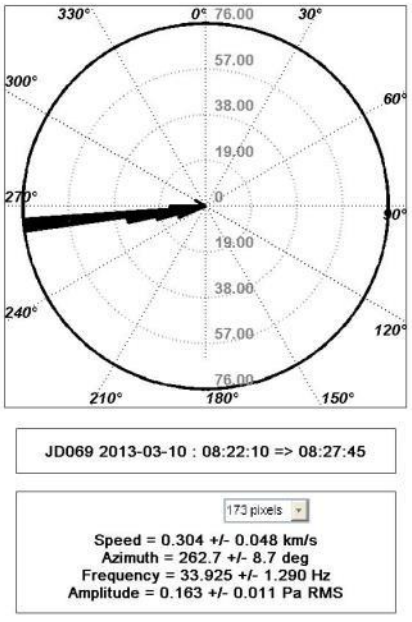
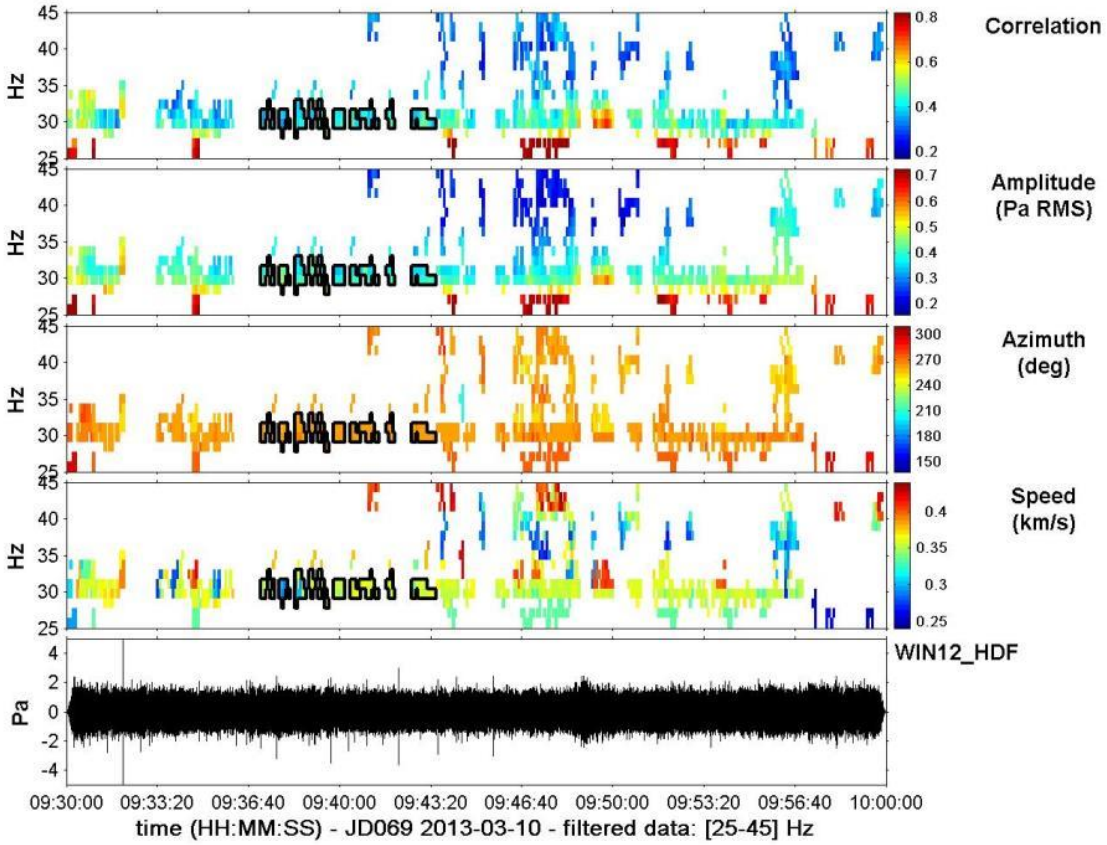
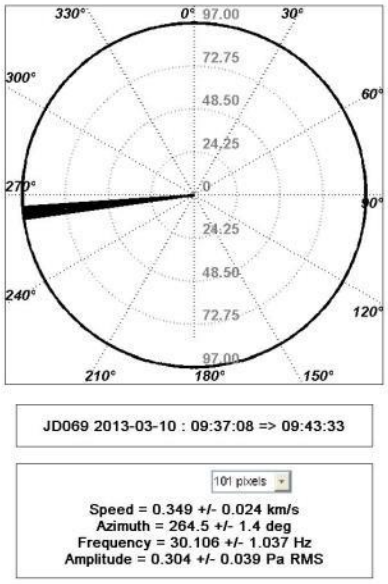

JD069 2013-03-10 : 08:22:10 => 08:27:45
173 pixels
Speed = 0.304 +/- 0.048 km/s
Azimuth = 262.7 +/- 8.7 deg
Frequency = 33.925 +/- 1.290 Hz
Amplitude = 0.163 +/- 0.011 Pa RMS

Figure A2-7





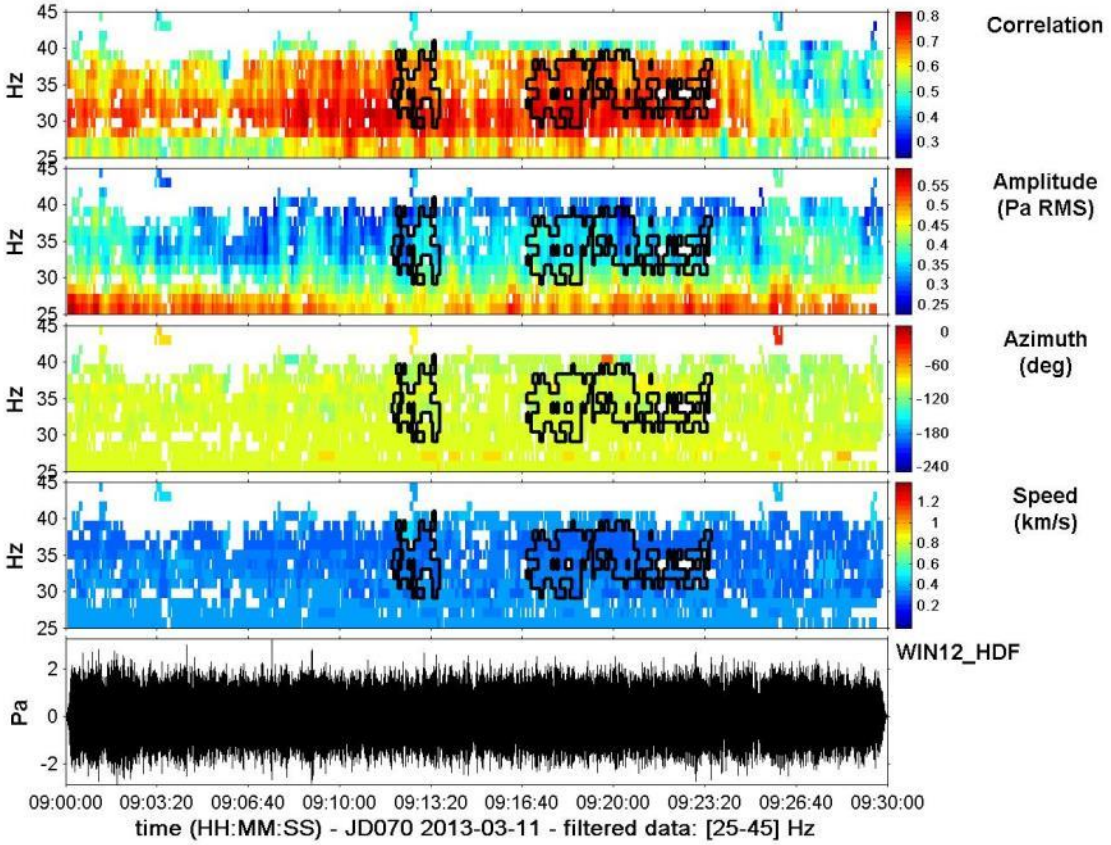
JD069 2013-03-10 : 09:37:08 => 09:43:33

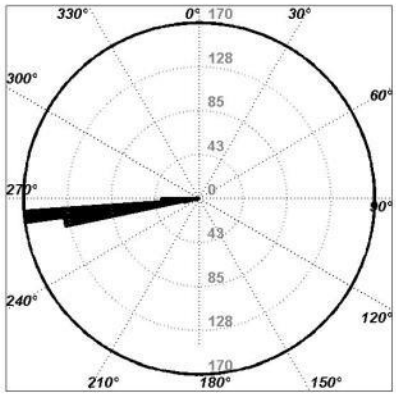
101 pixels

Speed = 0.349 +/- 0.024 km/s
Azimuth = 264.5 +/- 1.4 deg
Frequency = 30.106 +/- 1.037 Hz
Amplitude = 0.304 +/- 0.039 Pa RMS

Figure A2-8

20130311





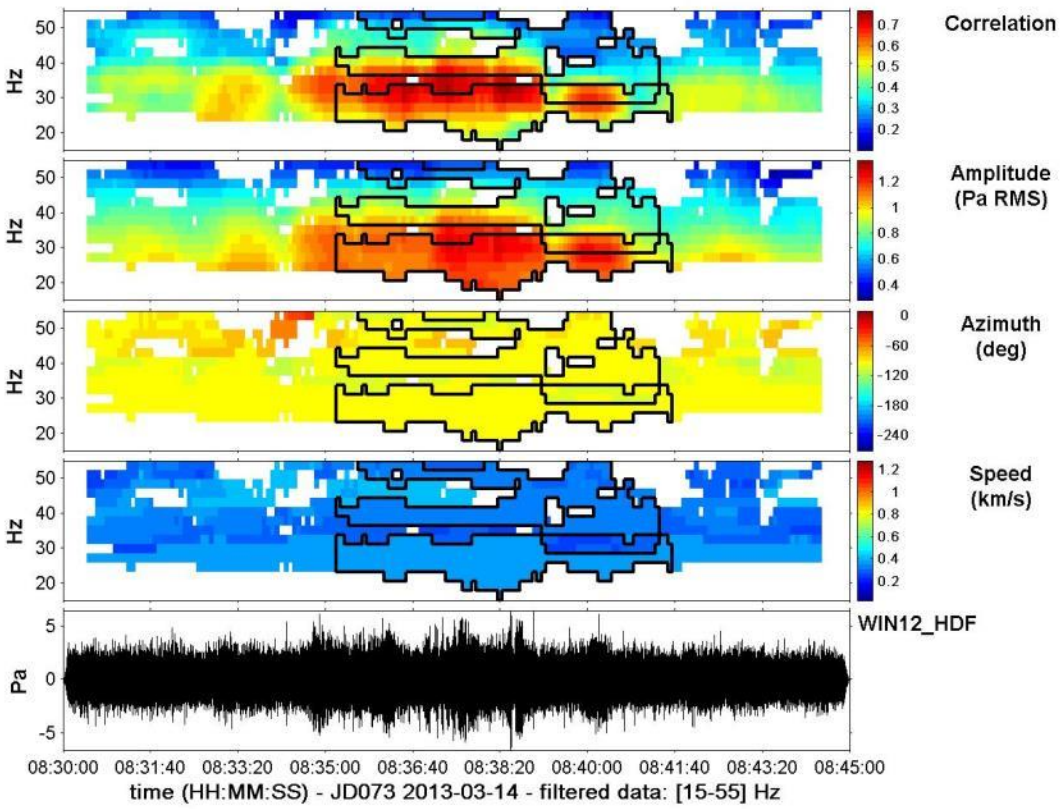
JD070 2013-03-11 : 09:11:55 => 09:23:35

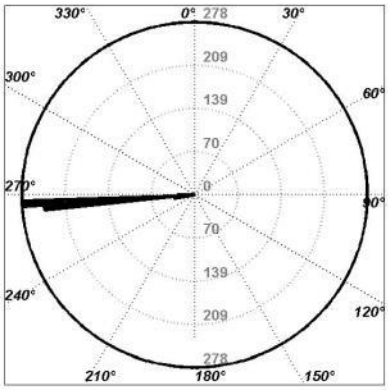
370 pixels

Speed = 0.307 +/- 0.016 km/s
Azimuth = 262.2 +/- 3.9 deg
Frequency = 34.344 +/- 2.608 Hz
Amplitude = 0.319 +/- 0.028 Pa RMS

Figure A2-9

20130314



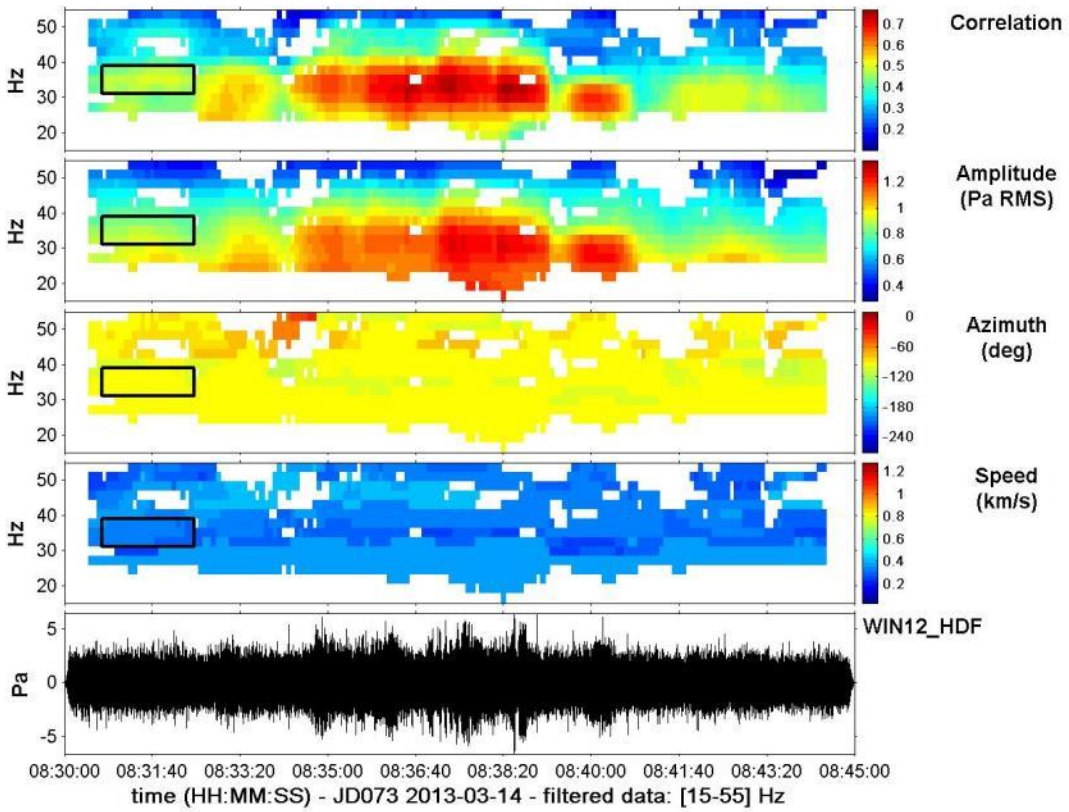


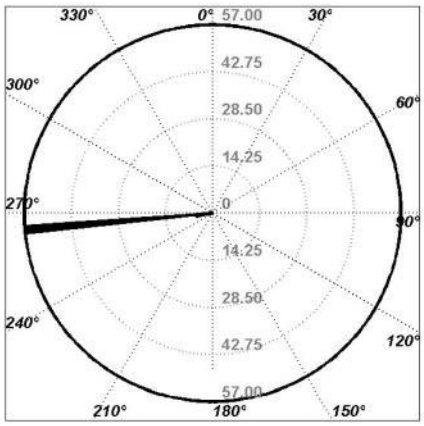
JD073 2013-03-14 : 08:35:13 => 08:41:37

600 pixels

Speed = 0.343 +/- 0.019 km/s
Azimuth = 265.9 +/- 2.1 deg
Frequency = 36.071 +/- 10.493 Hz
Amplitude = 0.794 +/- 0.245 Pa RMS

Figure A2-10



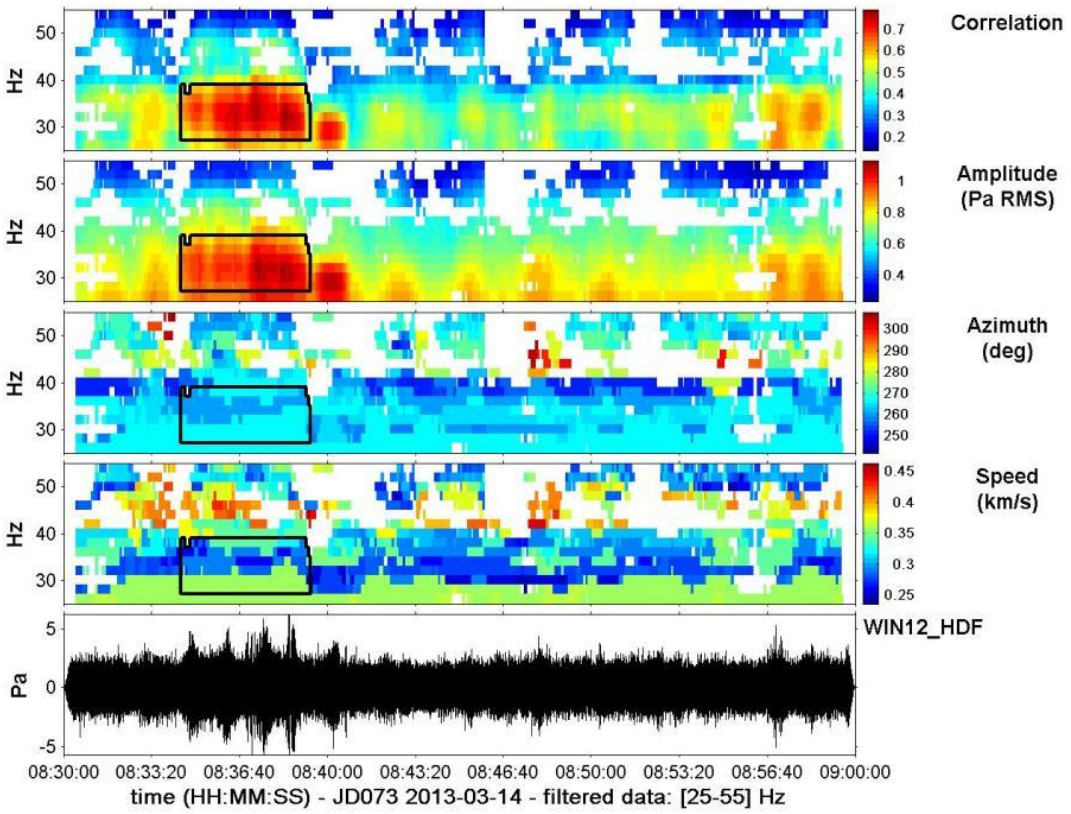


JD073 2013-03-14 : 08:30:43 => 08:32:28

63 pixels

Speed = 0.330 +/- 0.026 km/s
Azimuth = 265.0 +/- 2.1 deg
Frequency = 35.000 +/- 2.352 Hz
Amplitude = 0.670 +/- 0.041 Pa RMS

Figure A2-11


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
08:30:00 08:33:20 08:36:40 08:40:00 08:43:20 08:46:40 08:50:00 08:53:20 08:56:40 09:00:00
time (HH:MM:SS) - JD073 2013-03-14 - filtered data: [25-55] Hz

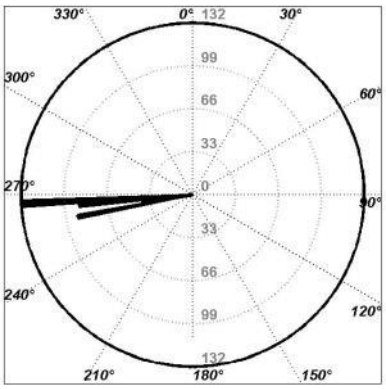
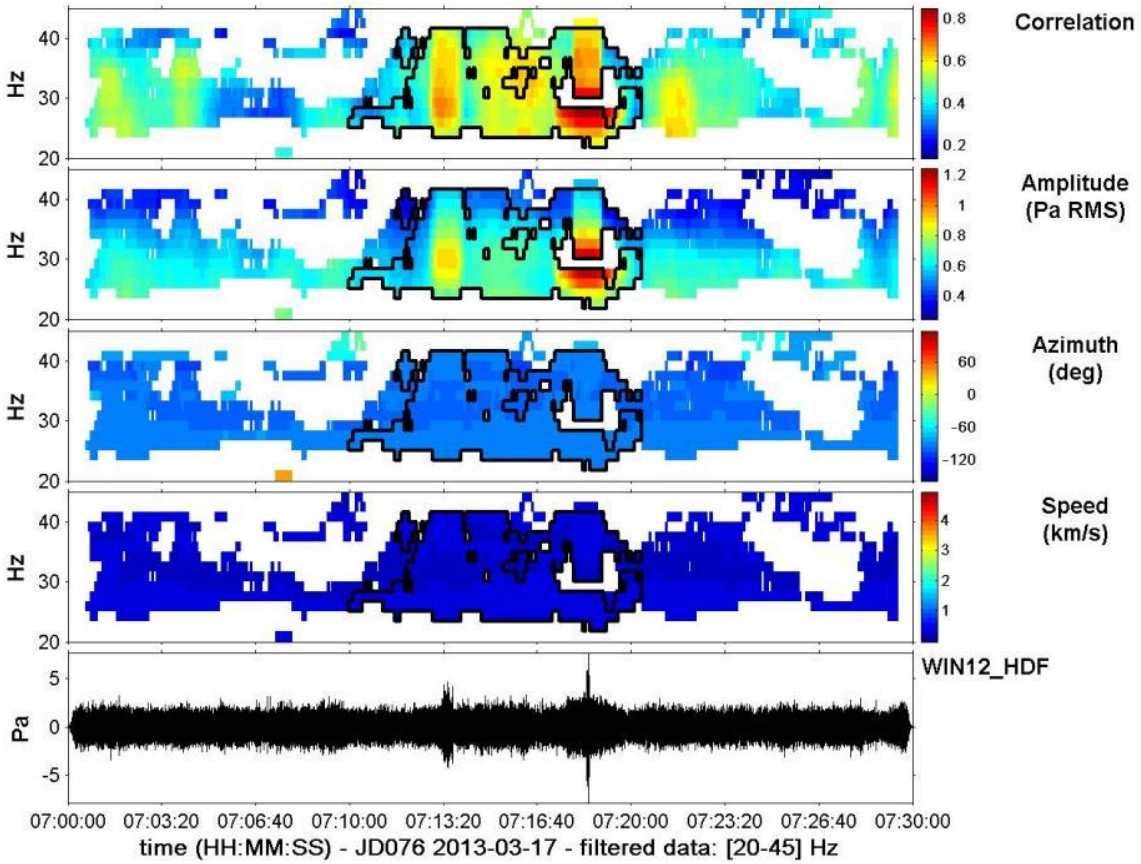

JD073 2013-03-14 : 08:34:27 => 08:39:22
349 pixels
Speed = 0.320 +/- 0.038 km/s
Azimuth = 263.8 +/- 3.2 deg
Frequency = 32.429 +/- 3.641 Hz
Amplitude = 0.871 +/- 0.113 Pa RMS

Figure A2-12

20130317



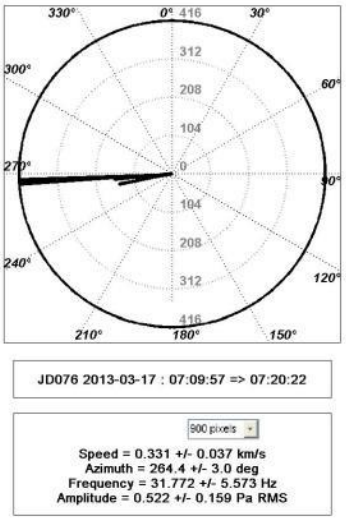
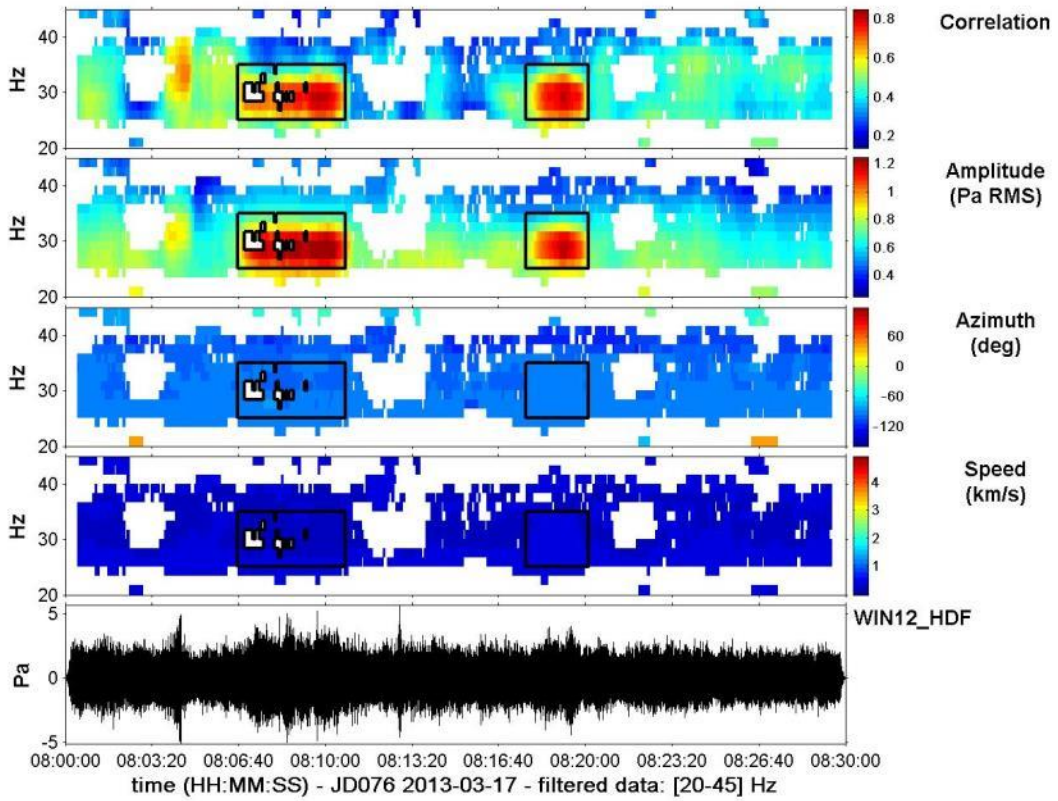
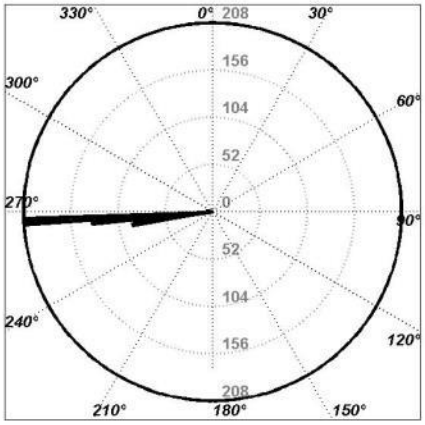


Figure A2-13





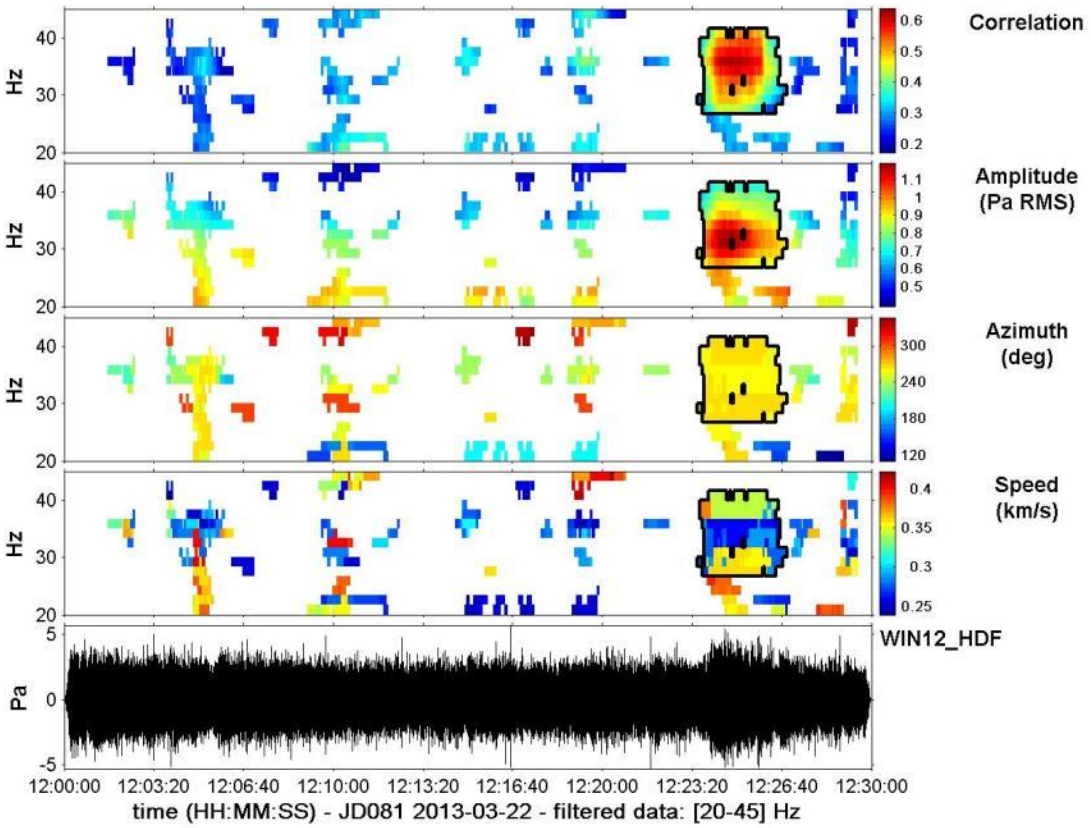
JD076 2013-03-17 : 08:06:38 => 08:20:08

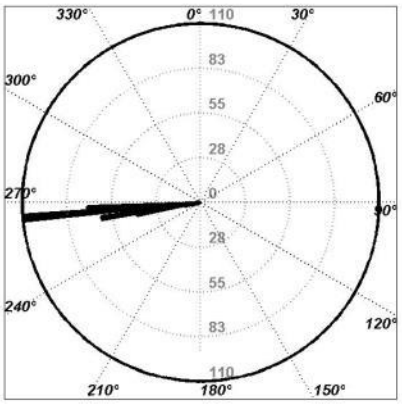
446 pixels

Speed = 0.317 +/- 0.046 km/s
Azimuth = 265.1 +/- 3.0 deg
Frequency = 29.821 +/- 3.126 Hz
Amplitude = 0.841 +/- 0.243 Pa RMS

Figure A2-14

20130322





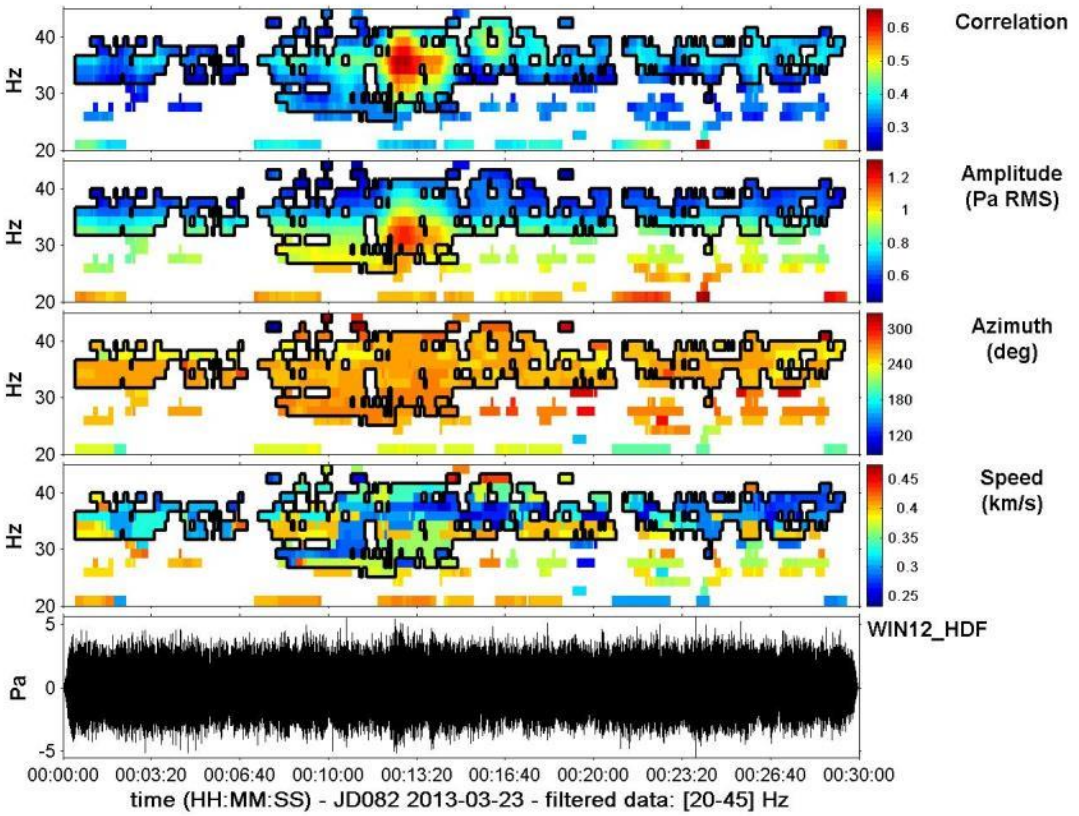
JD081 2013-03-22 : 12:23:33 => 12:26:53

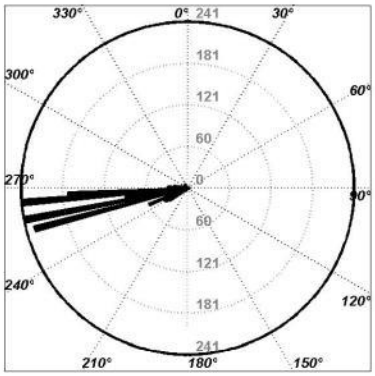
290 pixels

Speed = 0.315 +/- 0.041 km/s
Azimuth = 263.4 +/- 3.6 deg
Frequency = 34.028 +/- 4.479 Hz
Amplitude = 0.846 +/- 0.151 Pa RMS

Figure A2-15

20130323

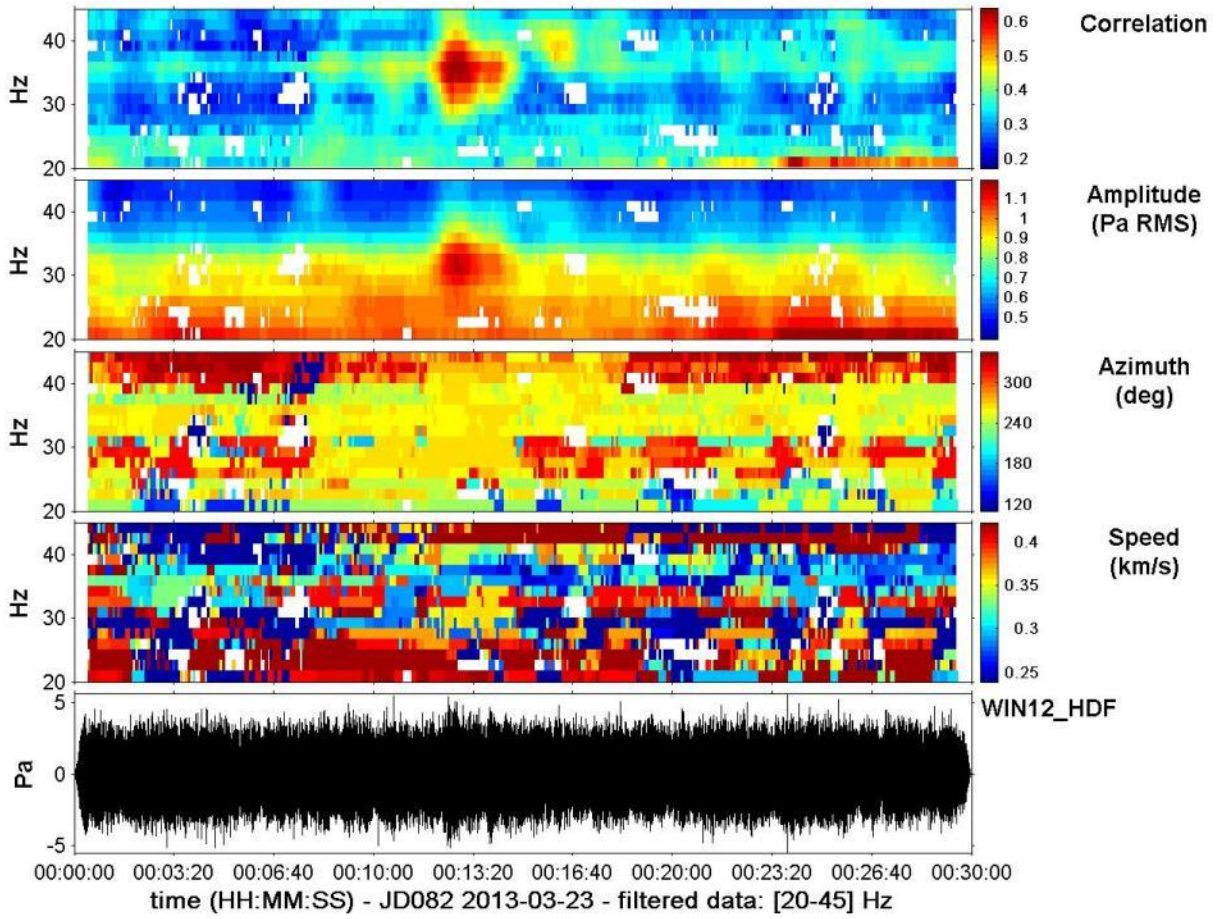


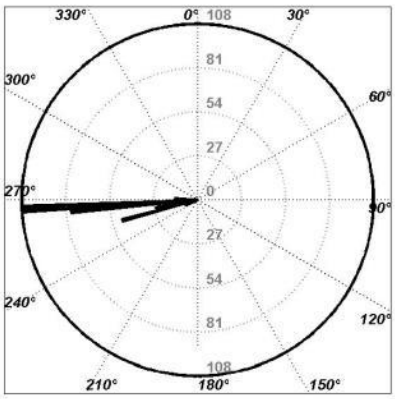


JD082 2013-03-23 : 00:00:28 => 00:29:28

Speed = 0.332 +/- 0.049 km/s
Azimuth = 259.4 +/- 15.8 deg
Frequency = 35.473 +/- 3.899 Hz
Amplitude = 0.667 +/- 0.140 Pa RMS

Figure A2-16



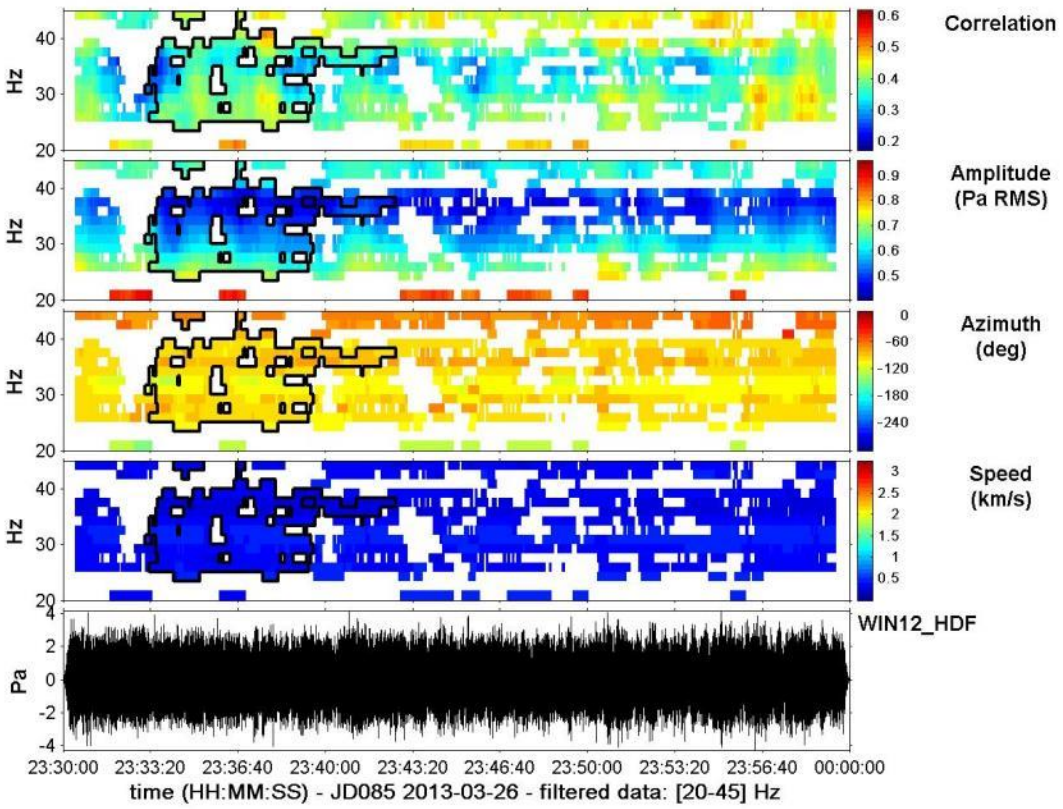


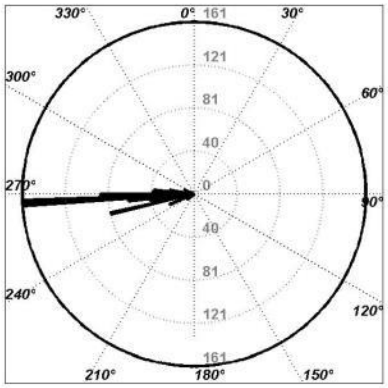
JD082 2013-03-23 : 00:11:48 => 00:14:43

Speed = 0.340 +/- 0.043 km/s
Azimuth = 263.3 +/- 5.5 deg
Frequency = 33.729 +/- 4.993 Hz
Amplitude = 0.826 +/- 0.164 Pa RMS

Figure A2-17

20130326





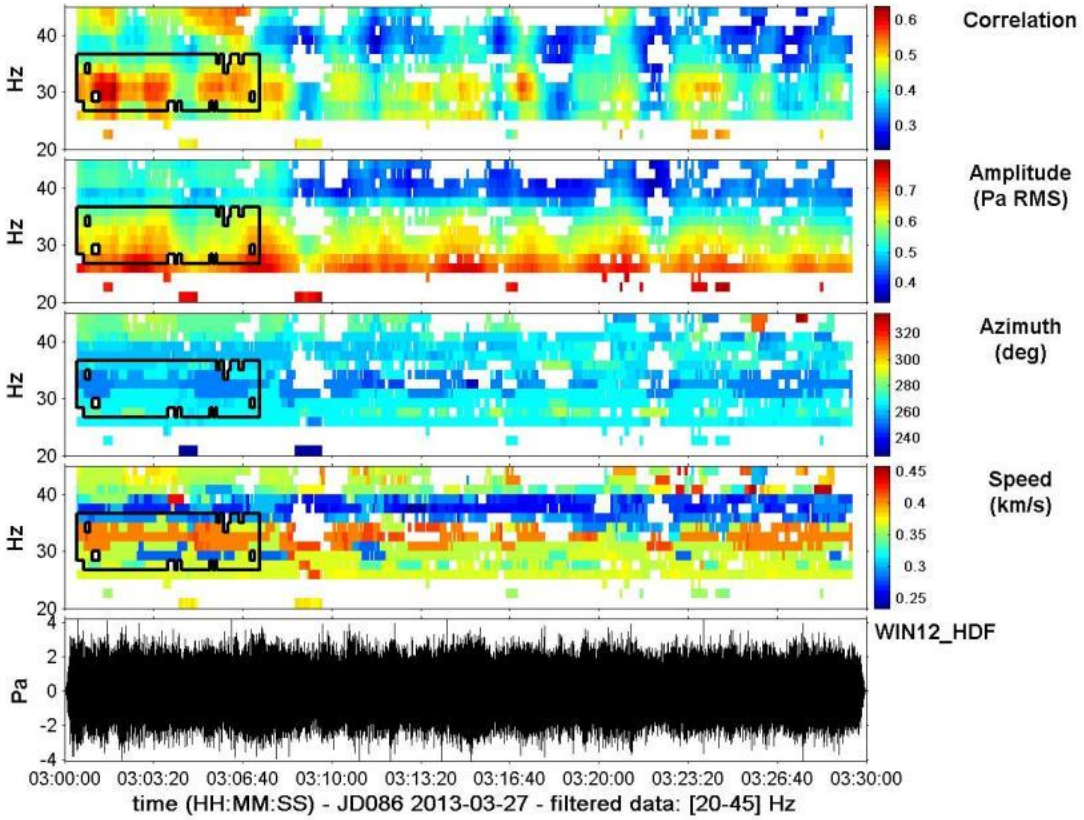
JD085 2013-03-26 : 23:33:07 => 23:42:42

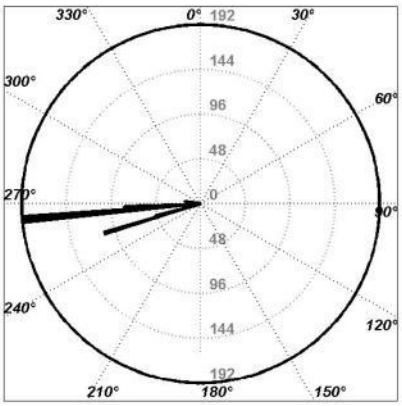
677 pixels

Speed = 0.350 +/- 0.055 km/s
Azimuth = 265.8 +/- 9.6 deg
Frequency = 32.946 +/- 5.294 Hz
Amplitude = 0.515 +/- 0.062 Pa RMS

Figure A2-18

20130327





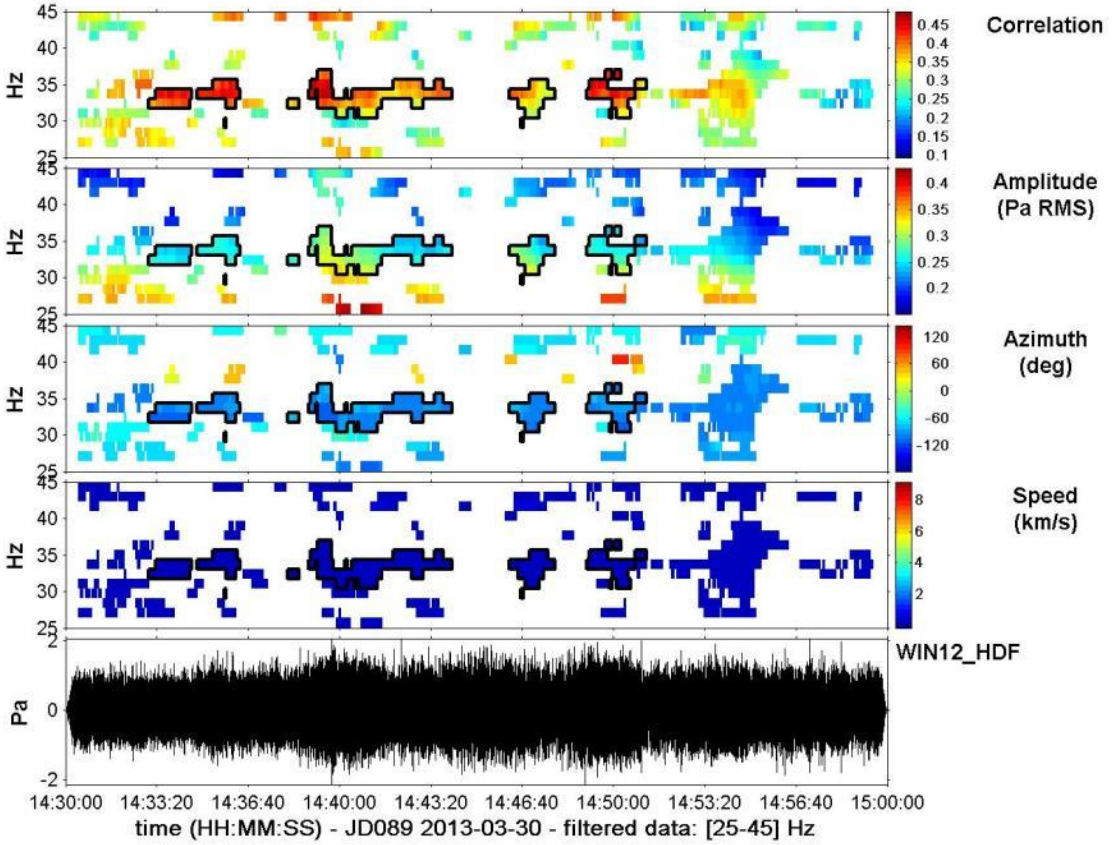
JD086 2013-03-27 : 03:00:28 => 03:07:18

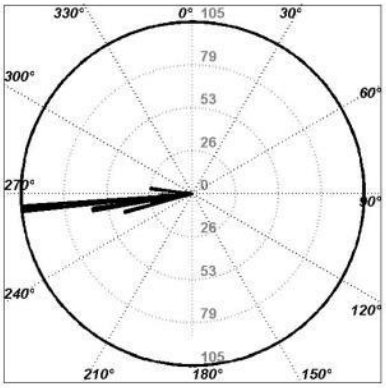
467 pixels

Speed = 0.358 +/- 0.046 km/s
Azimuth = 262.3 +/- 6.5 deg
Frequency = 31.651 +/- 2.999 Hz
Amplitude = 0.583 +/- 0.055 Pa RMS

Figure A2-19

20130330



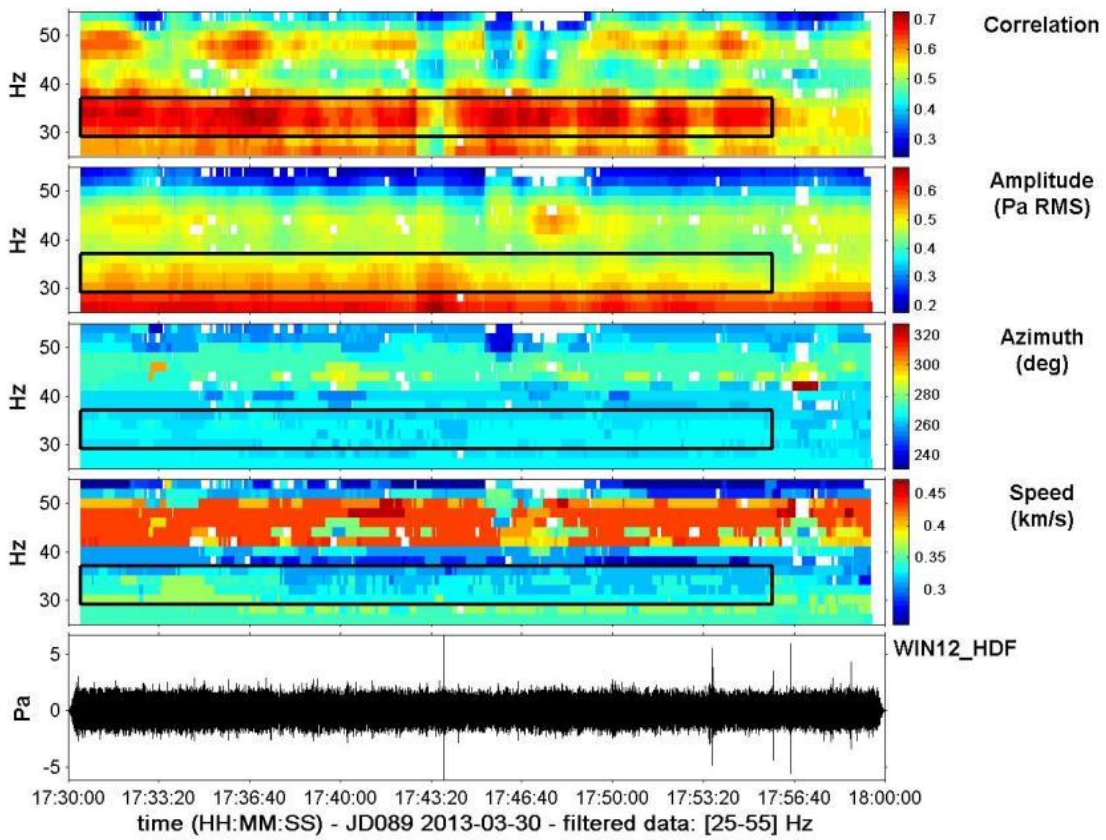


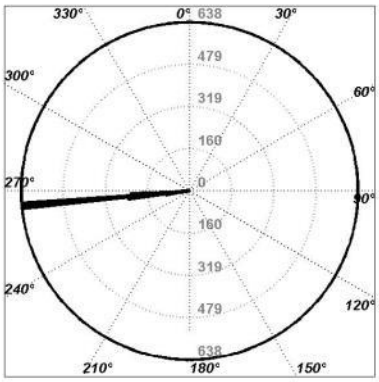
JD089 2013-03-30 : 14:33:02 => 14:51:12

306 pixels

Speed = 0.337 +/- 0.054 km/s
Azimuth = 264.0 +/- 6.2 deg
Frequency = 33.312 +/- 1.412 Hz
Amplitude = 0.239 +/- 0.025 Pa RMS

Figure A2-20



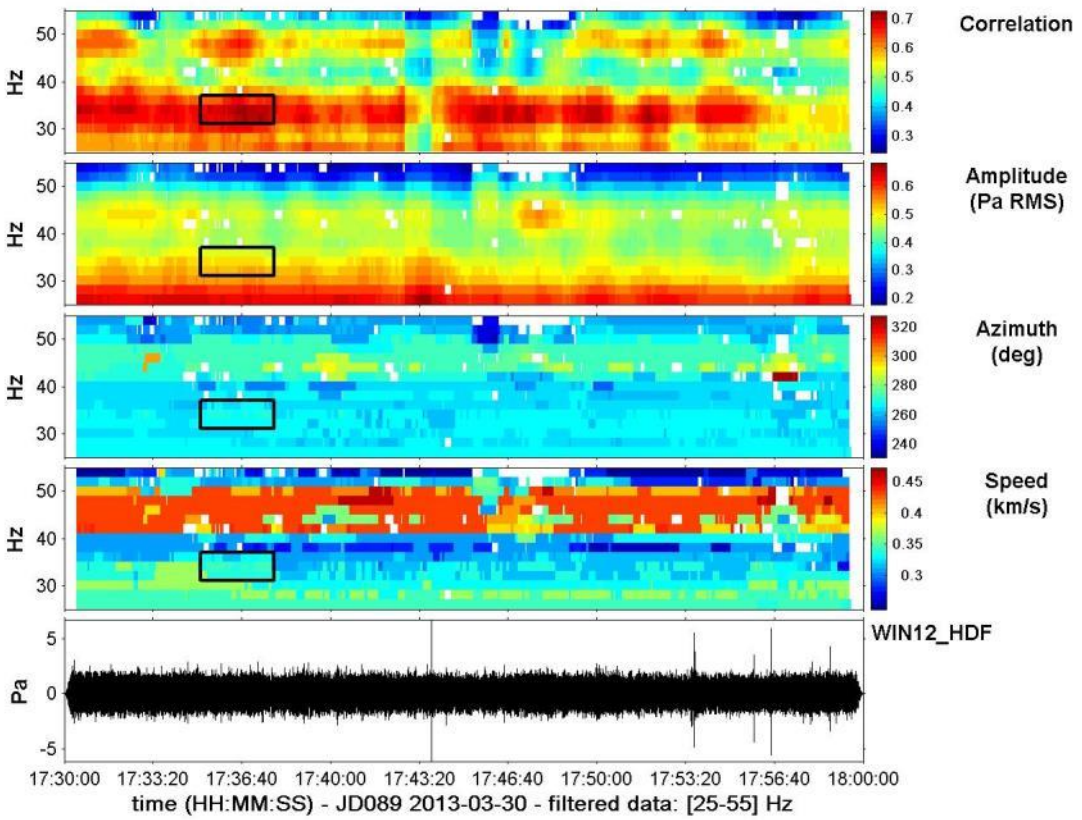


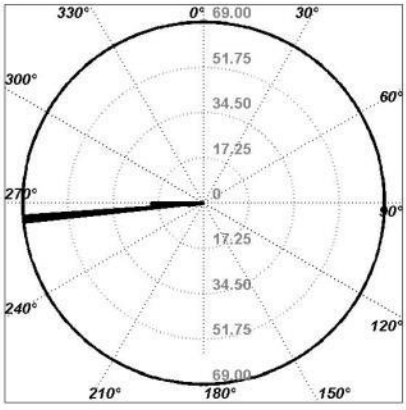
JD089 2013-03-30 : 17:30:28 => 17:55:52

1220 pix...

Speed = 0.329 +/- 0.016 km/s
Azimuth = 265.0 +/- 2.1 deg
Frequency = 32.500 +/- 2.397 Hz
Amplitude = 0.432 +/- 0.038 Pa RMS

Figure A2-21



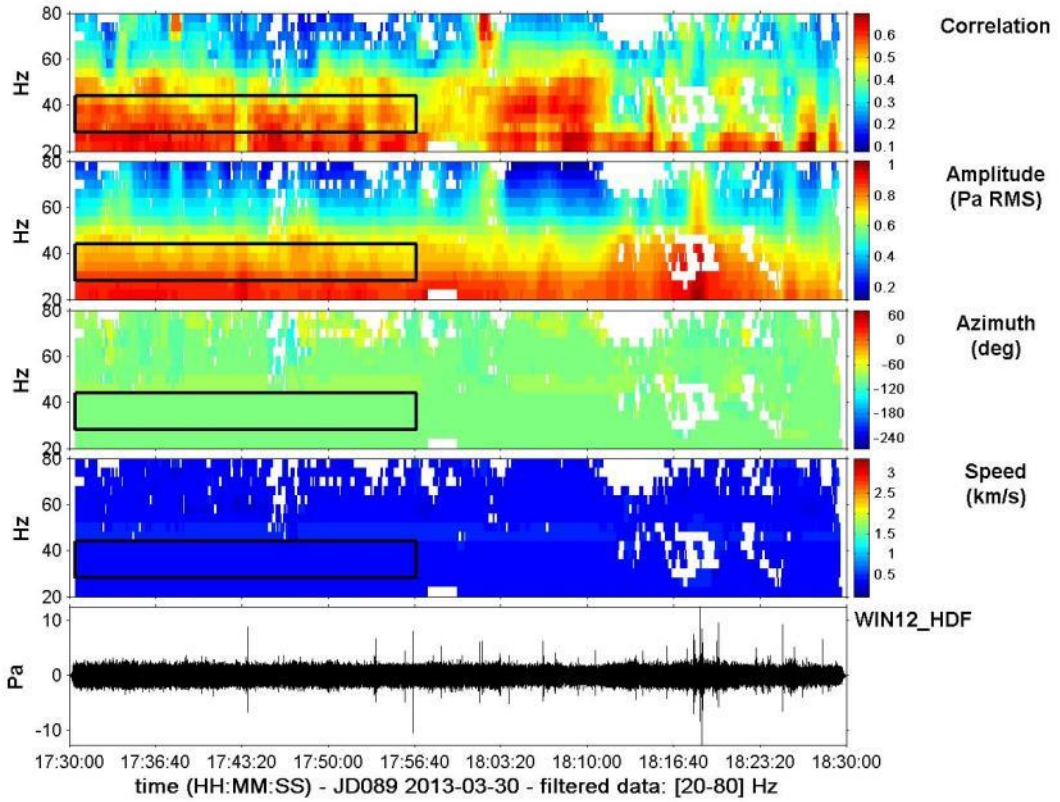


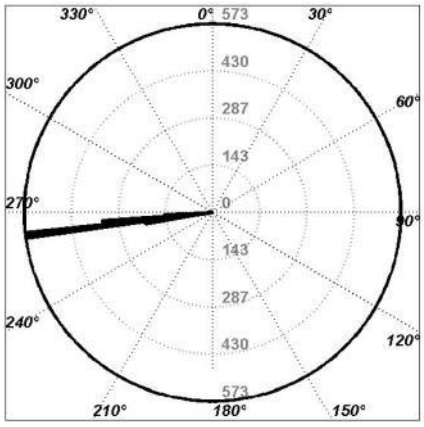
JD089 2013-03-30 : 17:35:08 => 17:37:53

99 pixels

Speed = 0.335 +/- 0.009 km/s
Azimuth = 266.0 +/- 2.3 deg
Frequency = 33.571 +/- 1.759 Hz
Amplitude = 0.435 +/- 0.027 Pa RMS

Figure A2-22

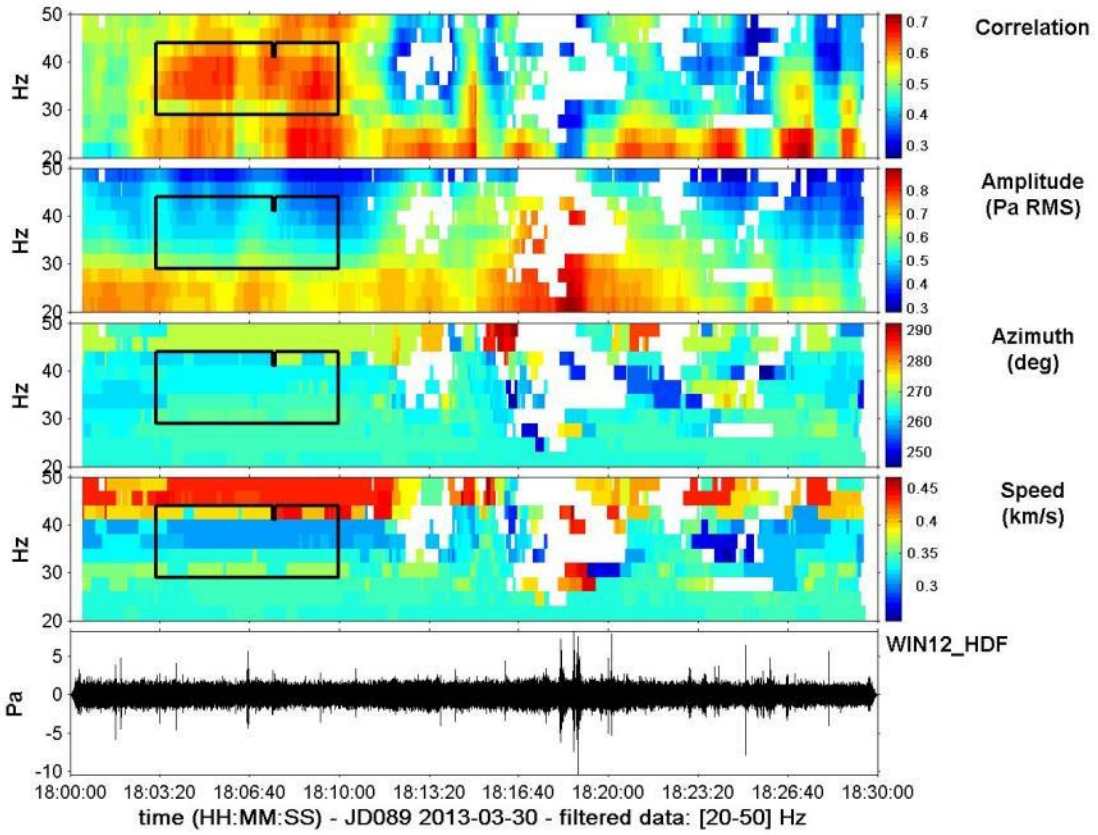




JD089 2013-03-30 : 17:30:28 => 17:56:48

Speed = 0.333 +/- 0.021 km/s
Azimuth = 263.9 +/- 1.8 deg
Frequency = 35.000 +/- 4.793 Hz
Amplitude = 0.594 +/- 0.068 Pa RMS

Figure A2-23


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
time (HH:MM:SS) - JD089 2013-03-30 - filtered data: [20-50] Hz

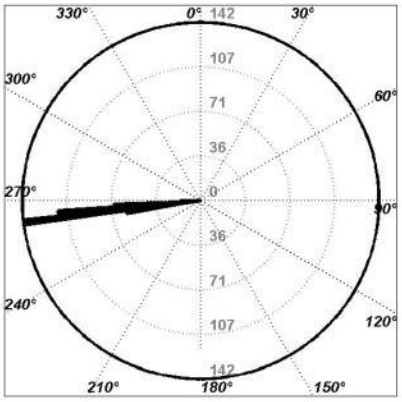
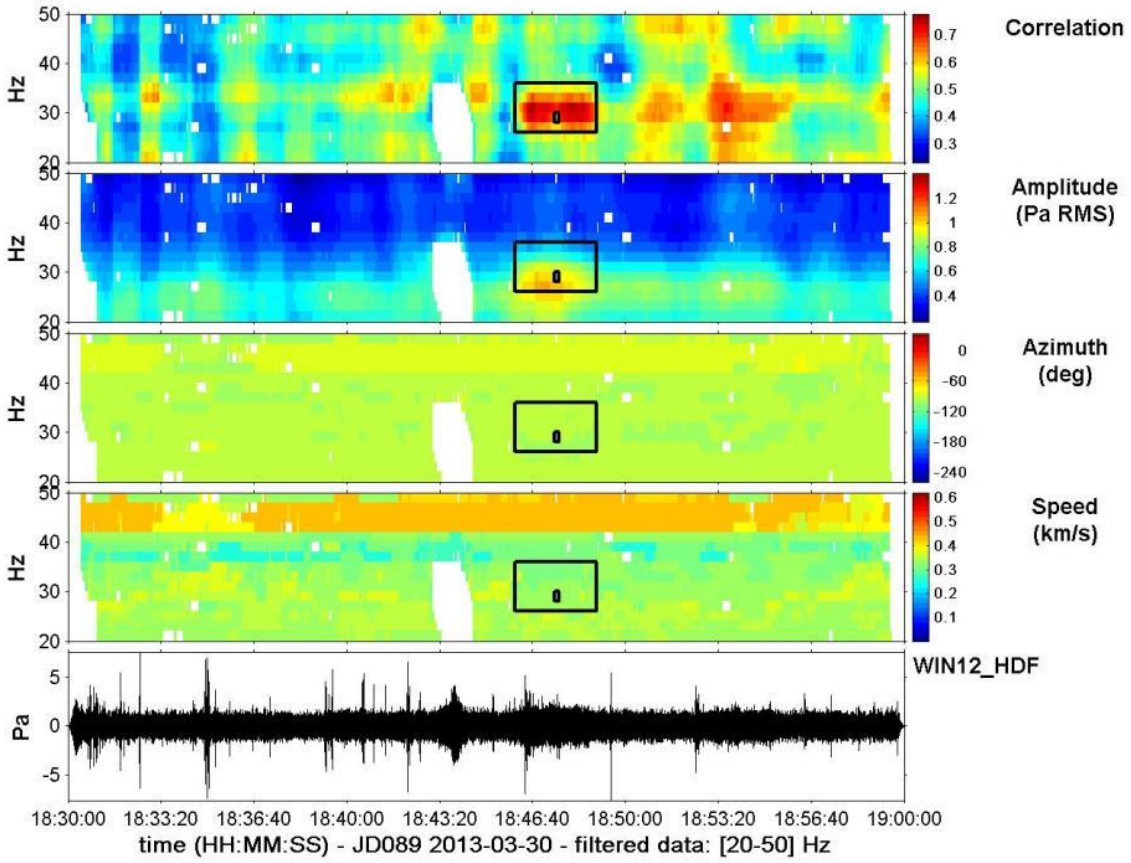
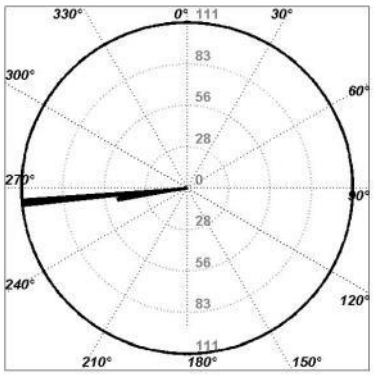

JD089 2013-03-30 : 18:03:13 => 18:09:58
404 pixels
Speed = 0.342 +/- 0.037 km/s
Azimuth = 264.7 +/- 2.4 deg
Frequency = 36.650 +/- 4.714 Hz
Amplitude = 0.450 +/- 0.044 Pa RMS

Figure A2-24



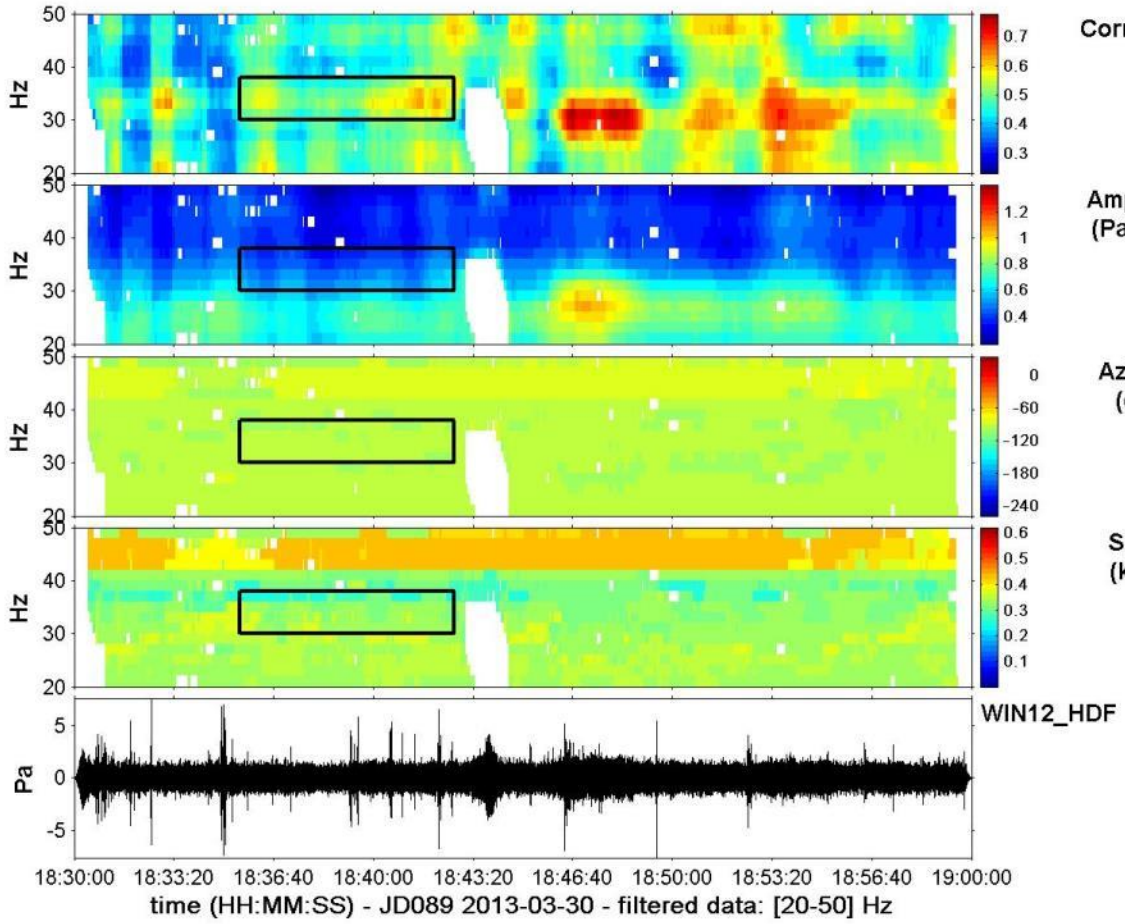


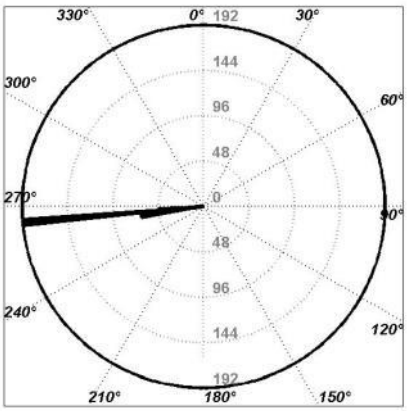
JD089 2013-03-30 : 18:46:03 => 18:48:58

170 pixels

Speed = 0.327 +/- 0.012 km/s
Azimuth = 263.7 +/- 1.8 deg
Frequency = 30.739 +/- 3.048 Hz
Amplitude = 0.555 +/- 0.151 Pa RMS

Figure A2-25



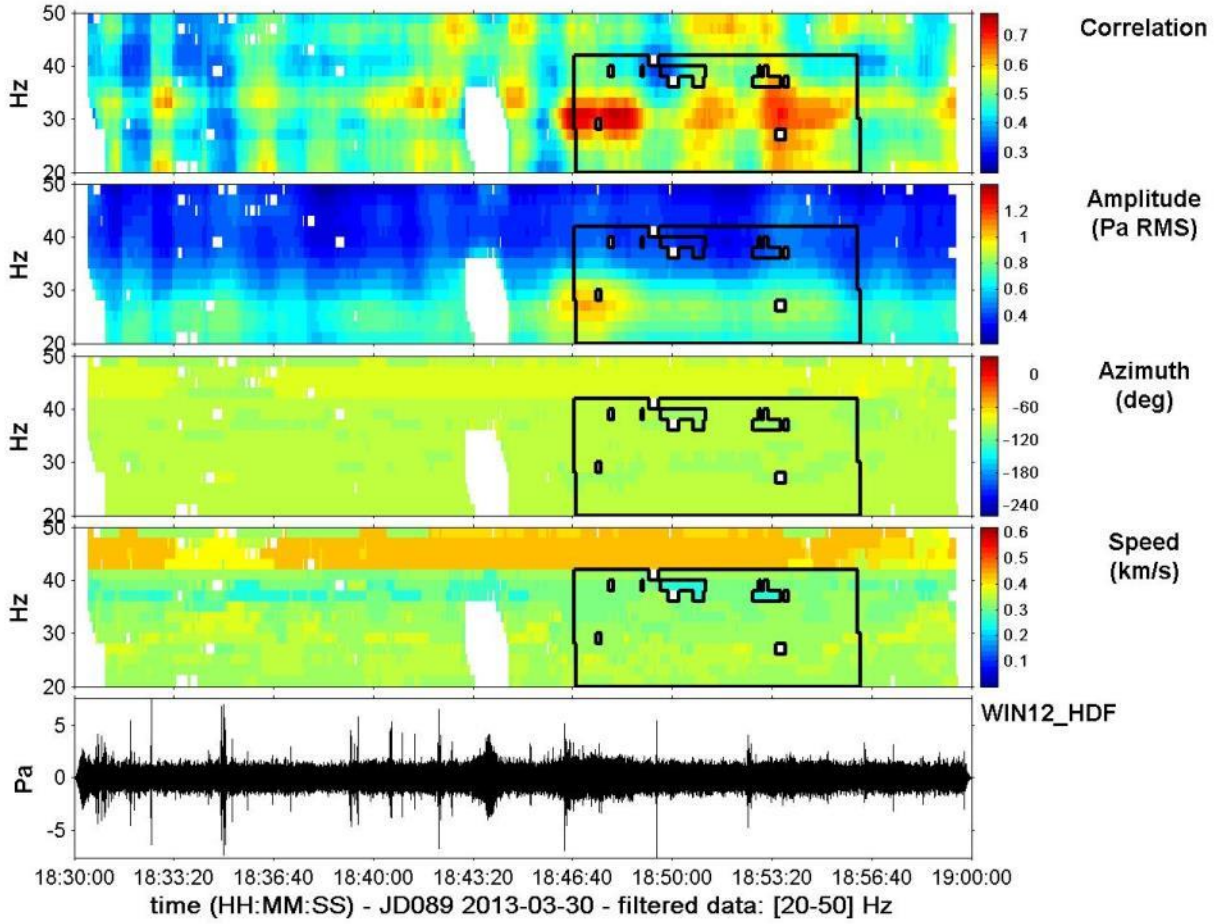


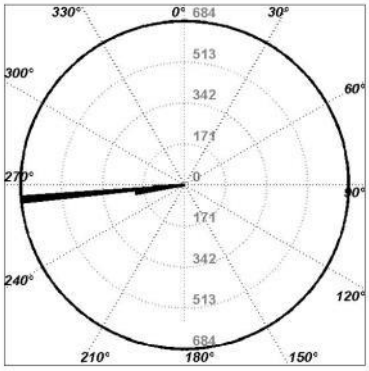
JD089 2013-03-30 : 18:35:33 => 18:42:43

344 pixels

Speed = 0.320 +/- 0.030 km/s
Azimuth = 264.5 +/- 2.3 deg
Frequency = 33.929 +/- 2.399 Hz
Amplitude = 0.315 +/- 0.034 Pa RMS

Figure A2-26





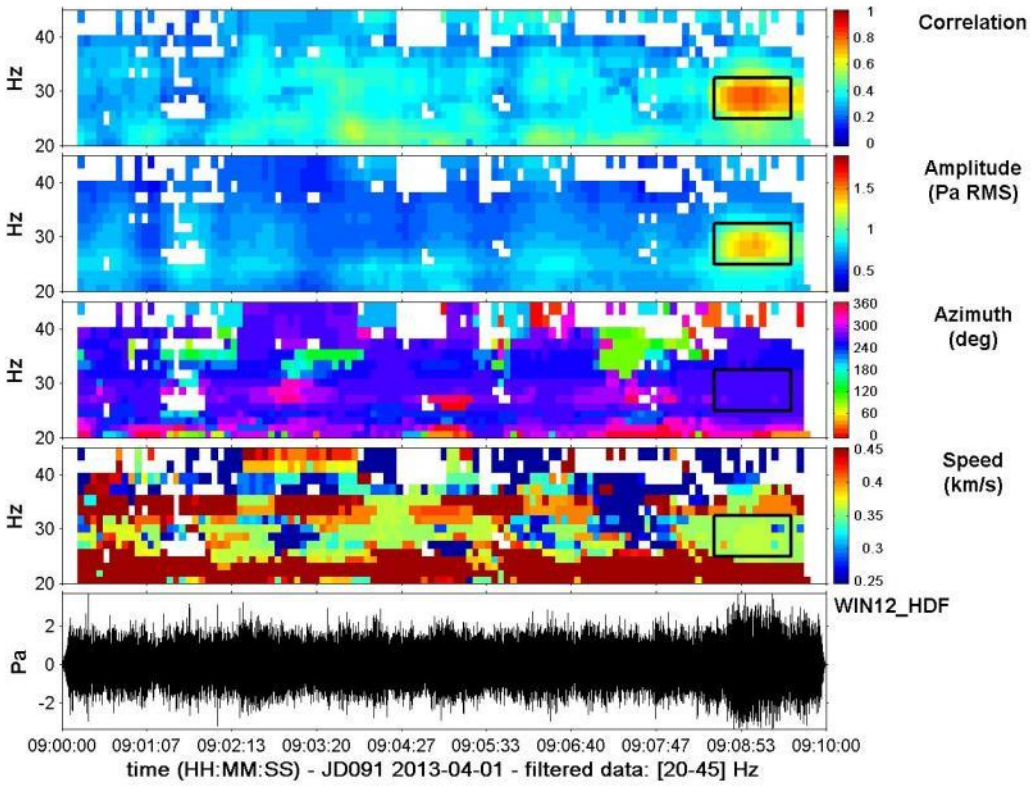
JD089 2013-03-30 : 18:46:43 => 18:56:18

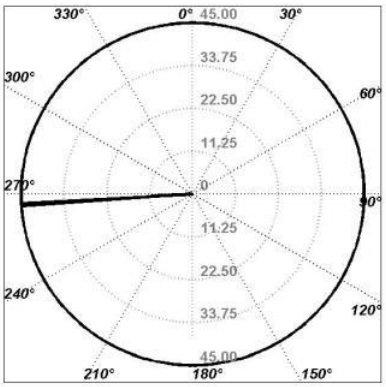
1200 pts...

Speed = 0.331 +/- 0.014 km/s
Azimuth = 264.2 +/- 2.0 deg
Frequency = 30.411 +/- 6.730 Hz
Amplitude = 0.431 +/- 0.127 Pa RMS

Figure A2-27

20130401



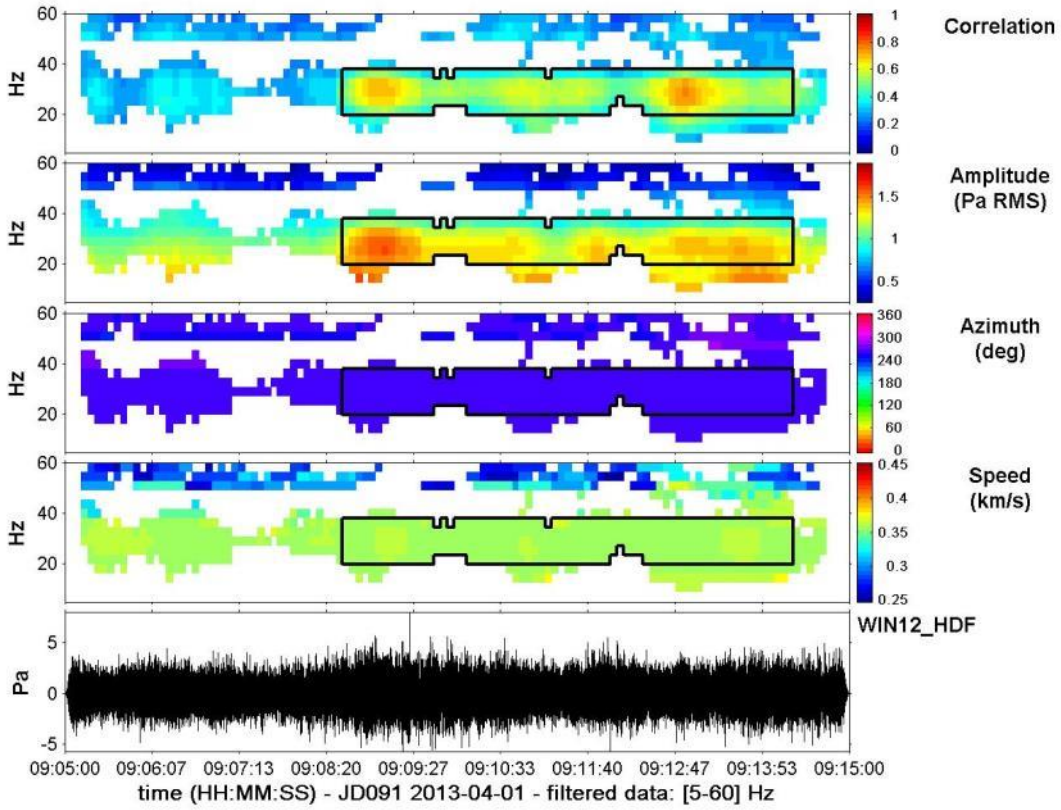


JD091 2013-04-01 : 09:08:33 => 09:09:33

60 pixels

Speed = 0.358 +/- 0.015 km/s
Azimuth = 267.2 +/- 2.7 deg
Frequency = 30.714 +/- 2.547 Hz
Amplitude = 0.851 +/- 0.147 Pa RMS

Figure A2-28


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
09:05:00 09:06:07 09:07:13 09:08:20 09:09:27 09:10:33 09:11:40 09:12:47 09:13:53 09:15:00
time (HH:MM:SS) - JD091 2013-04-01 - filtered data: [5-60] Hz

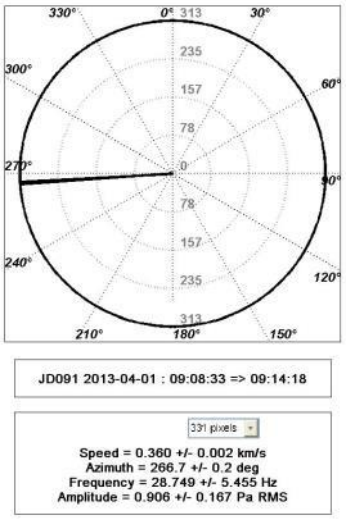
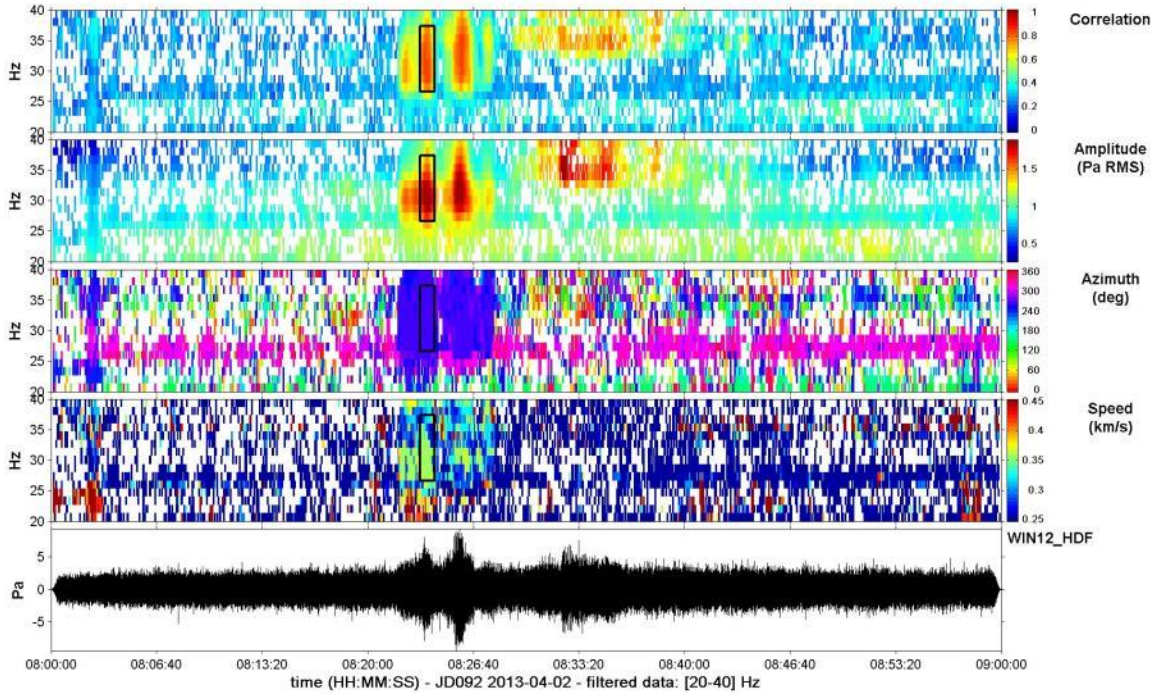
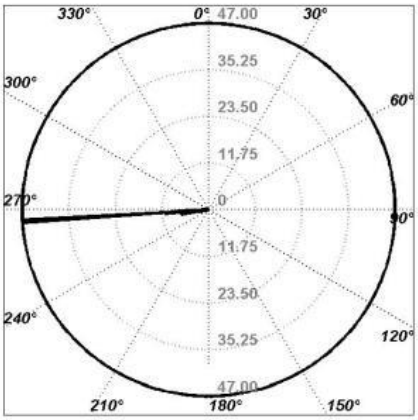

JD091 2013-04-01 : 09:08:33 => 09:14:18
331 pixels
Speed = 0.360 +/- 0.002 km/s
Azimuth = 266.7 +/- 0.2 deg
Frequency = 28.749 +/- 5.455 Hz
Amplitude = 0.906 +/- 0.167 Pa RMS

Figure A2-29

20130402



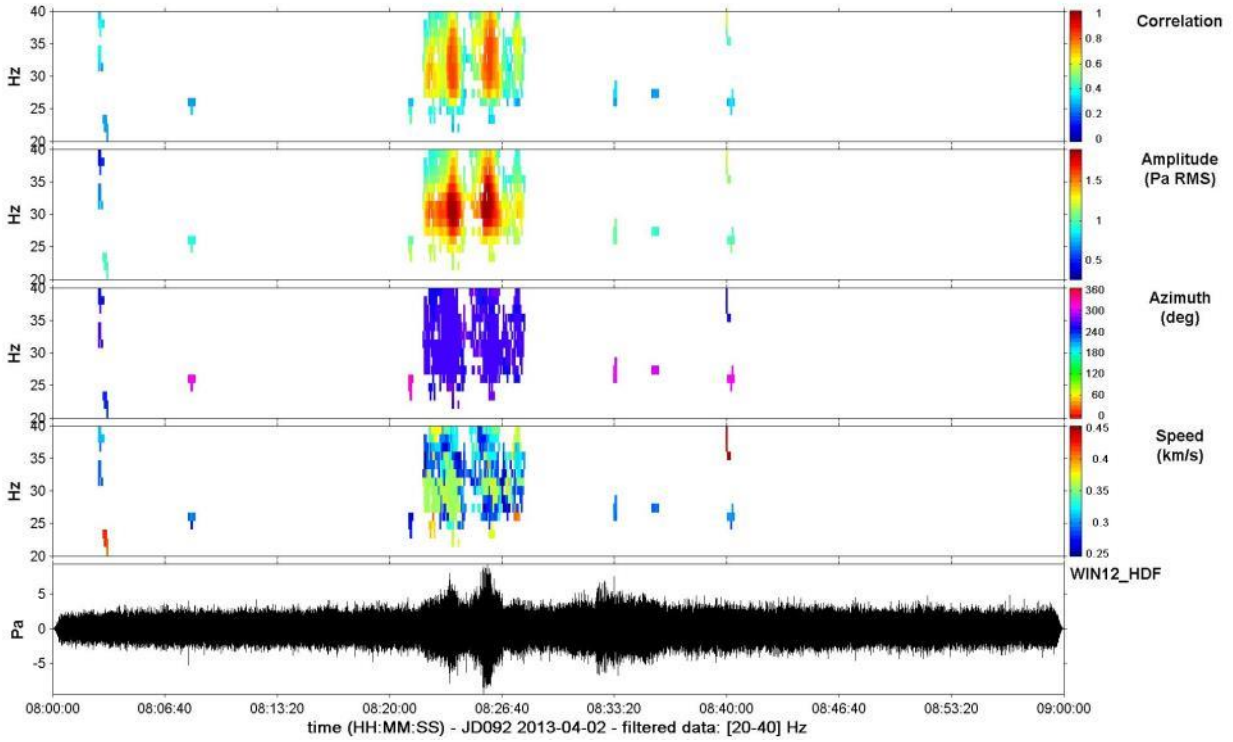


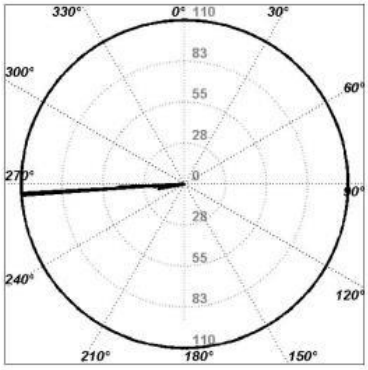
JD092 2013-04-02 : 08:23:18 => 08:24:13

66 pixels

Speed = 0.335 +/- 0.039 km/s
Azimuth = 265.0 +/- 2.9 deg
Frequency = 32.143 +/- 3.292 Hz
Amplitude = 1.405 +/- 0.351 Pa RMS

Figure A2-30



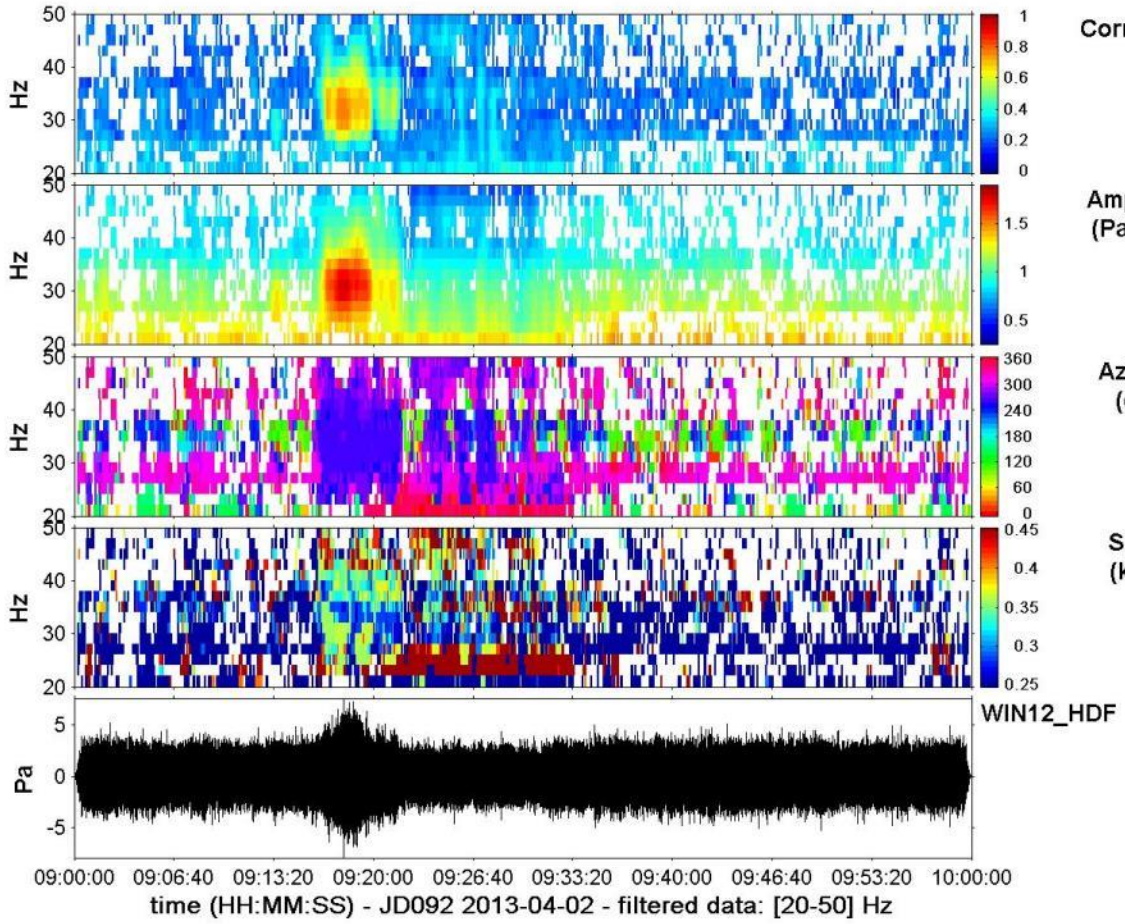


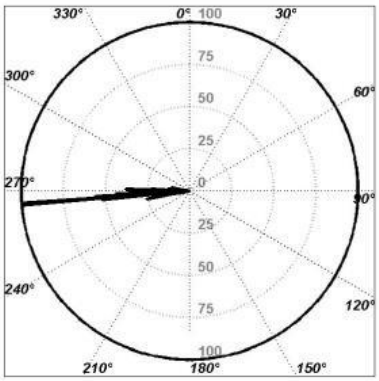
JD092 2013-04-02 : 08:21:58 => 08:26:33

236 pixels

Speed = 0.339 +/- 0.033 km/s
Azimuth = 265.4 +/- 2.7 deg
Frequency = 32.197 +/- 4.011 Hz
Amplitude = 1.222 +/- 0.400 Pa RMS

Figure A2-31





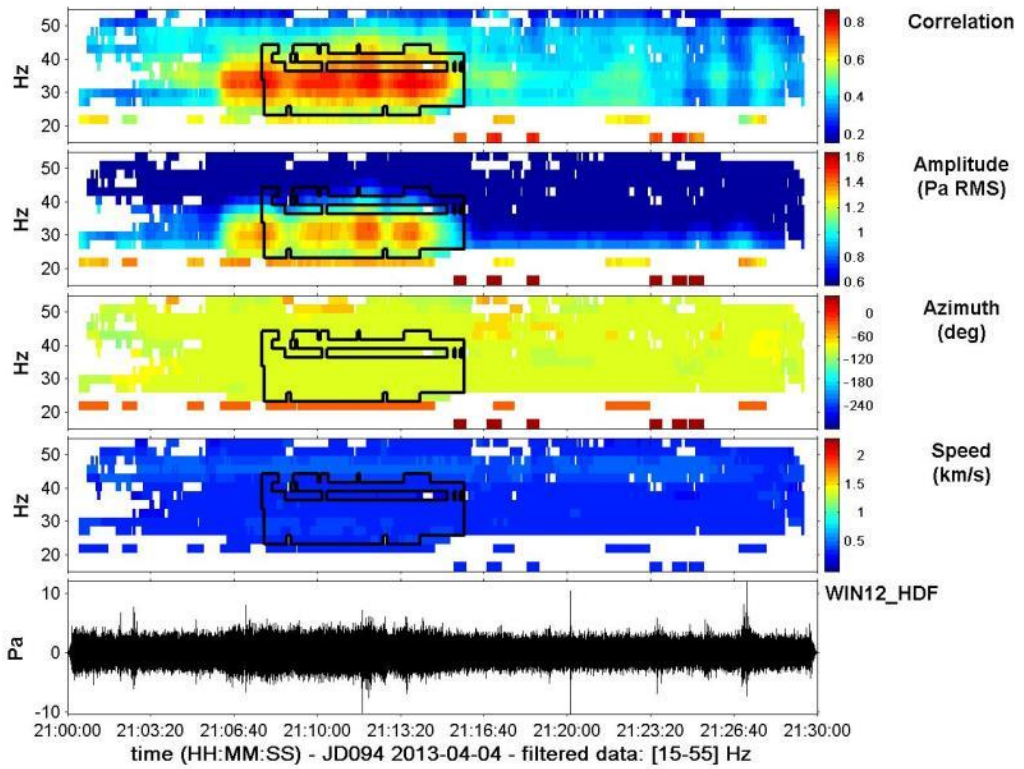
JD092 2013-04-02 : 09:16:23 => 09:21:53

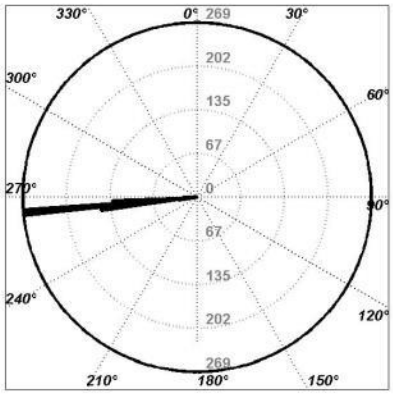
495 pixels

Speed = 0.330 +/- 0.036 km/s
Azimuth = 267.0 +/- 5.2 deg
Frequency = 34.043 +/- 5.635 Hz
Amplitude = 1.010 +/- 0.286 Pa RMS

Figure A2-32

20130404



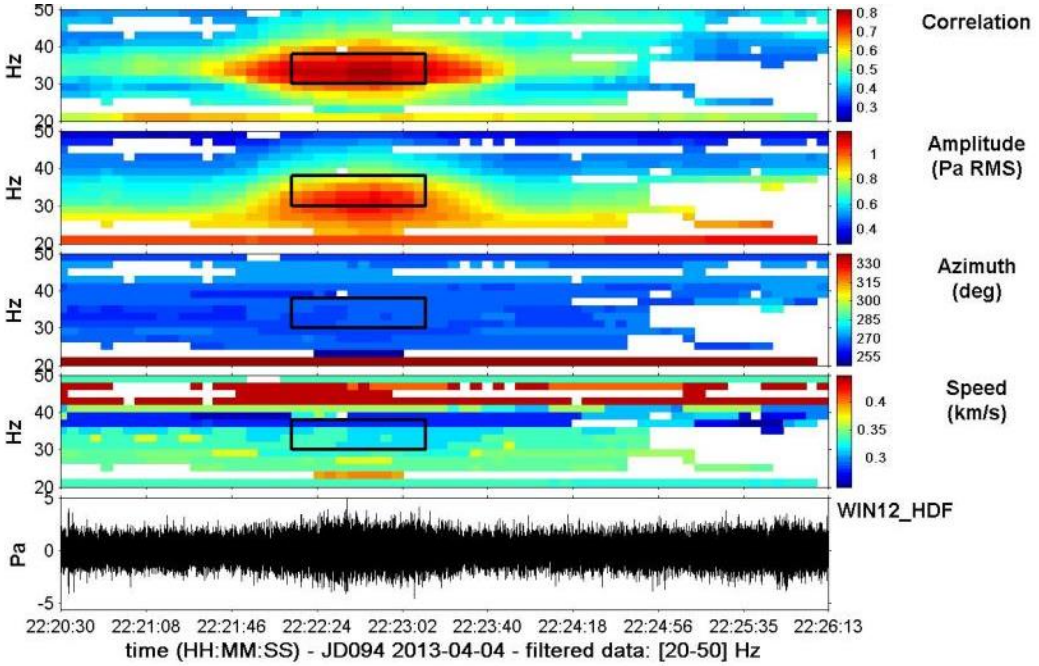


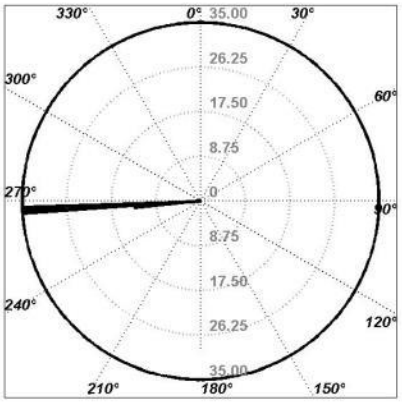
JD094 2013-04-04 : 21:07:48 => 21:15:53

600 pixels

Speed = 0.335 +/- 0.019 km/s
Azimuth = 265.4 +/- 1.9 deg
Frequency = 32.367 +/- 6.043 Hz
Amplitude = 1.006 +/- 0.207 Pa RMS

Figure A2-33



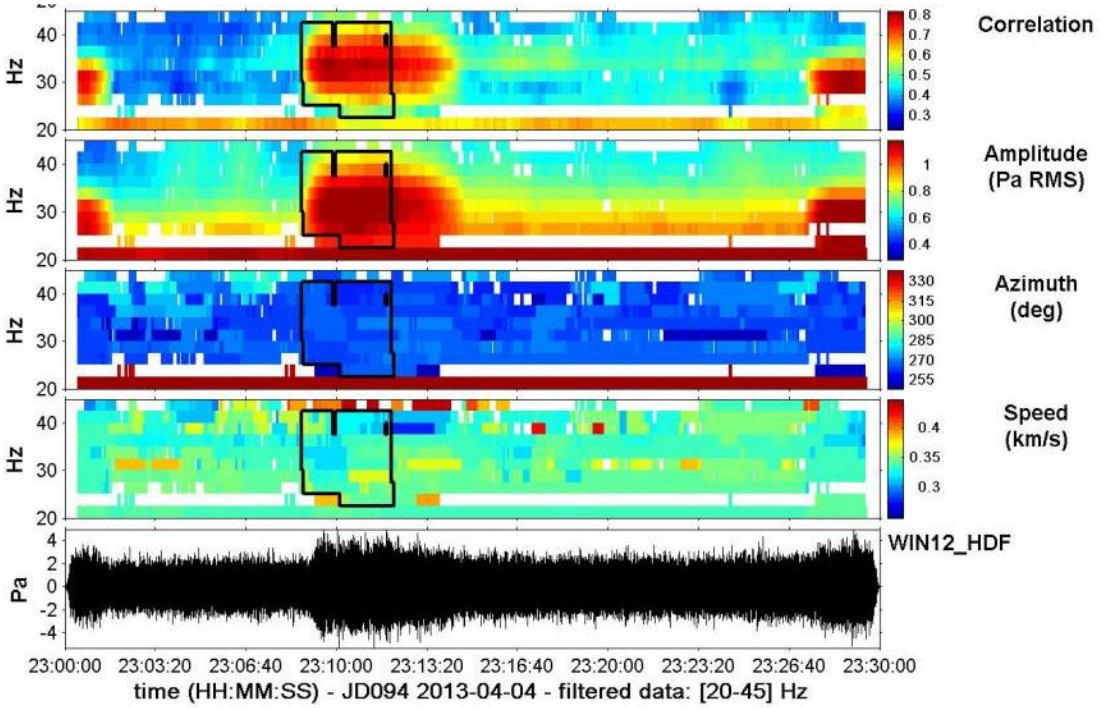


JD094 2013-04-04 : 22:22:13 => 22:23:13

40 pixels

Speed = 0.311 +/- 0.021 km/s
Azimuth = 267.2 +/- 1.1 deg
Frequency = 33.929 +/- 2.421 Hz
Amplitude = 0.862 +/- 0.122 Pa RMS

Figure A2-34


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
23:00:00 23:03:20 23:06:40 23:10:00 23:13:20 23:16:40 23:20:00 23:23:20 23:26:40 23:30:00
time (HH:MM:SS) - JD094 2013-04-04 - filtered data: [20-45] Hz

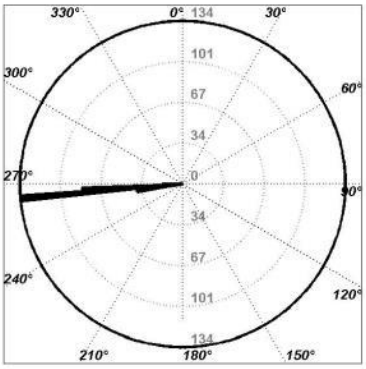
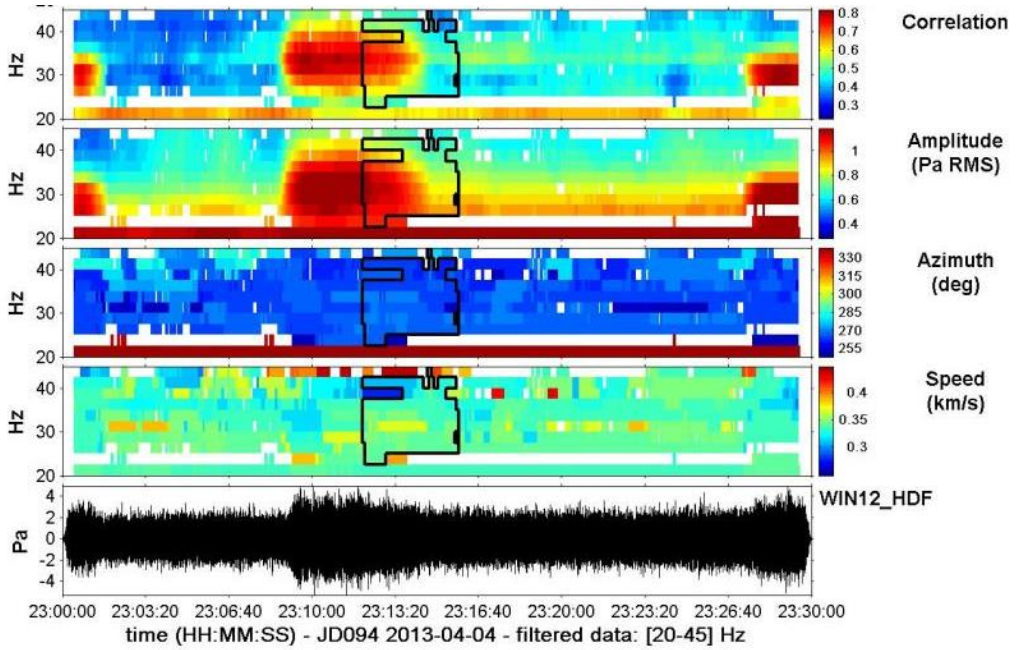
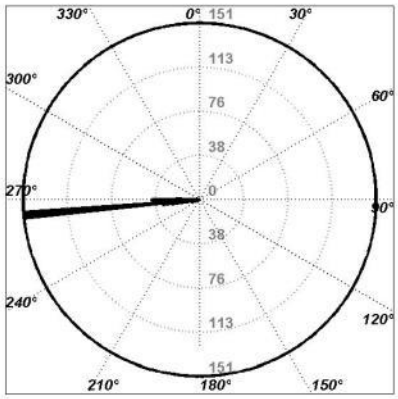

JD094 2013-04-04 : 23:08:43 => 23:12:08
300 pixels
Speed = 0.334 +/- 0.016 km/s
Azimuth = 265.6 +/- 2.2 deg
Frequency = 32.954 +/- 6.115 Hz
Amplitude = 1.024 +/- 0.229 Pa RMS

Figure A2-35





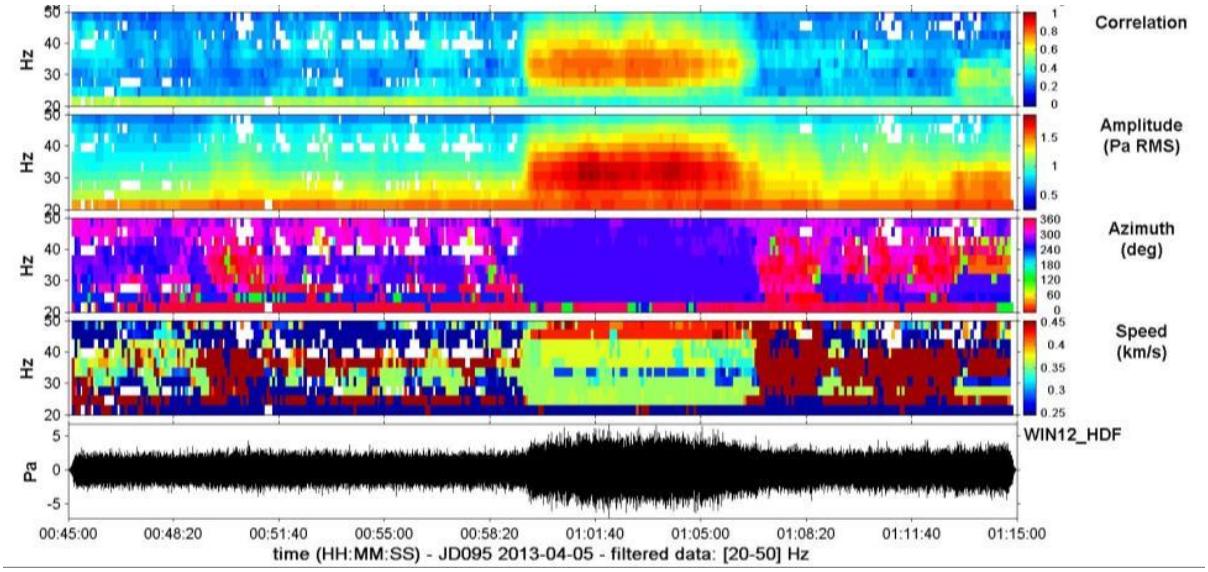
JD094 2013-04-04 : 23:12:03 => 23:15:53

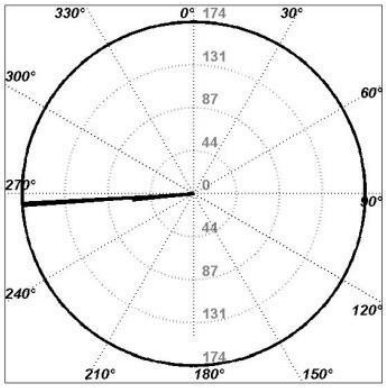
300 pixels

Speed = 0.339 +/- 0.014 km/s
Azimuth = 265.7 +/- 3.0 deg
Frequency = 33.000 +/- 5.750 Hz
Amplitude = 0.827 +/- 0.194 Pa RMS

Figure A2-36

20130405



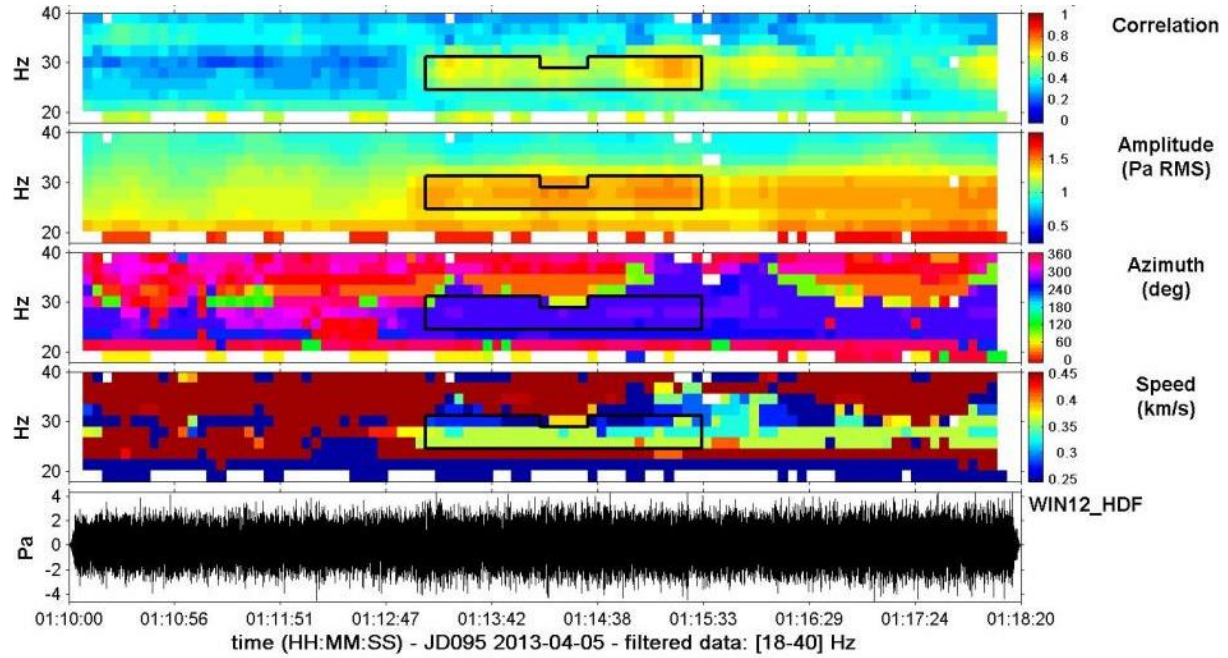


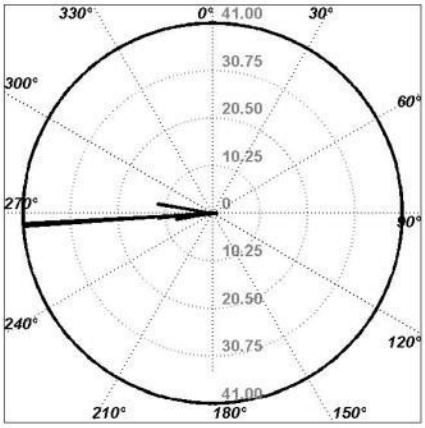
JD095 2013-04-05 : 00:59:33 => 01:05:38

292 pixels

Speed = 0.347 +/- 0.027 km/s
Azimuth = 265.9 +/- 1.1 deg
Frequency = 31.667 +/- 3.733 Hz
Amplitude = 1.530 +/- 0.160 Pa RMS

Figure A2-37



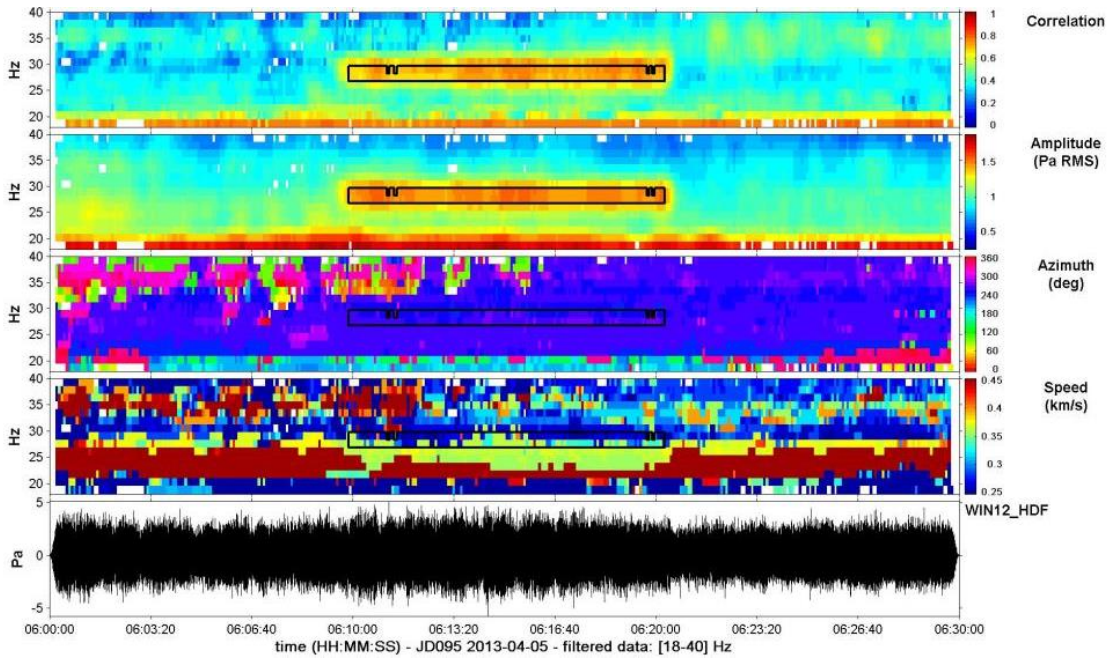


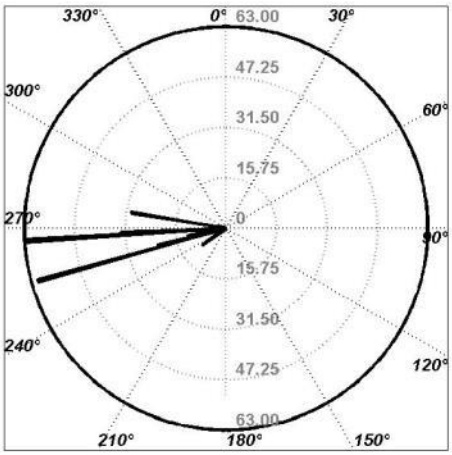
JD095 2013-04-05 : 01:13:08 => 01:15:33

82 pixels

Speed = 0.331 +/- 0.043 km/s
Azimuth = 267.5 +/- 20.3 deg
Frequency = 27.629 +/- 1.972 Hz
Amplitude = 1.103 +/- 0.046 Pa RMS

Figure A2-38



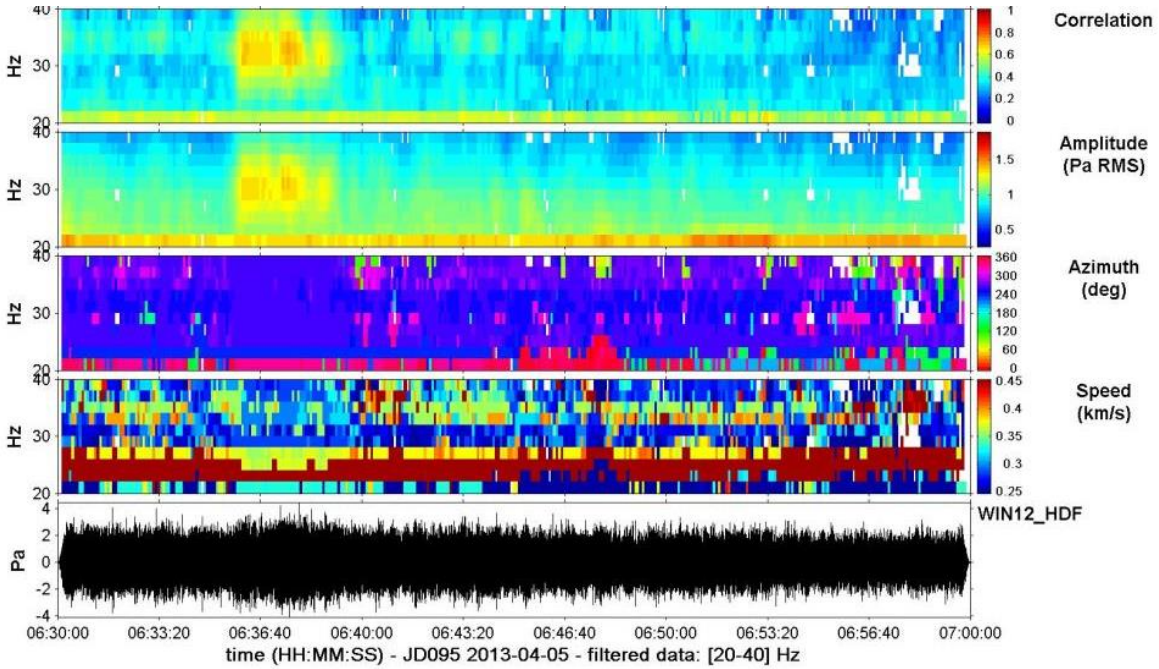


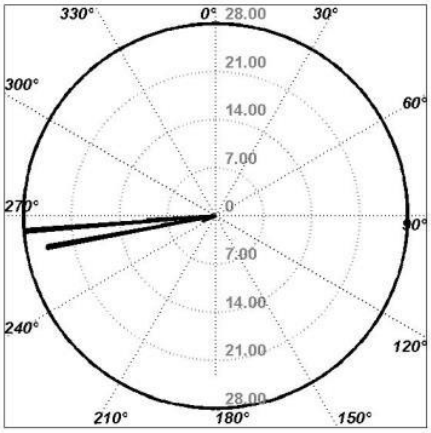
JD095 2013-04-05 : 06:09:53 => 06:20:18

246 pixels

Speed = 0.300 +/- 0.059 km/s
Azimuth = 262.9 +/- 10.2 deg
Frequency = 28.202 +/- 0.787 Hz
Amplitude = 1.183 +/- 0.052 Pa RMS

Figure A2-39



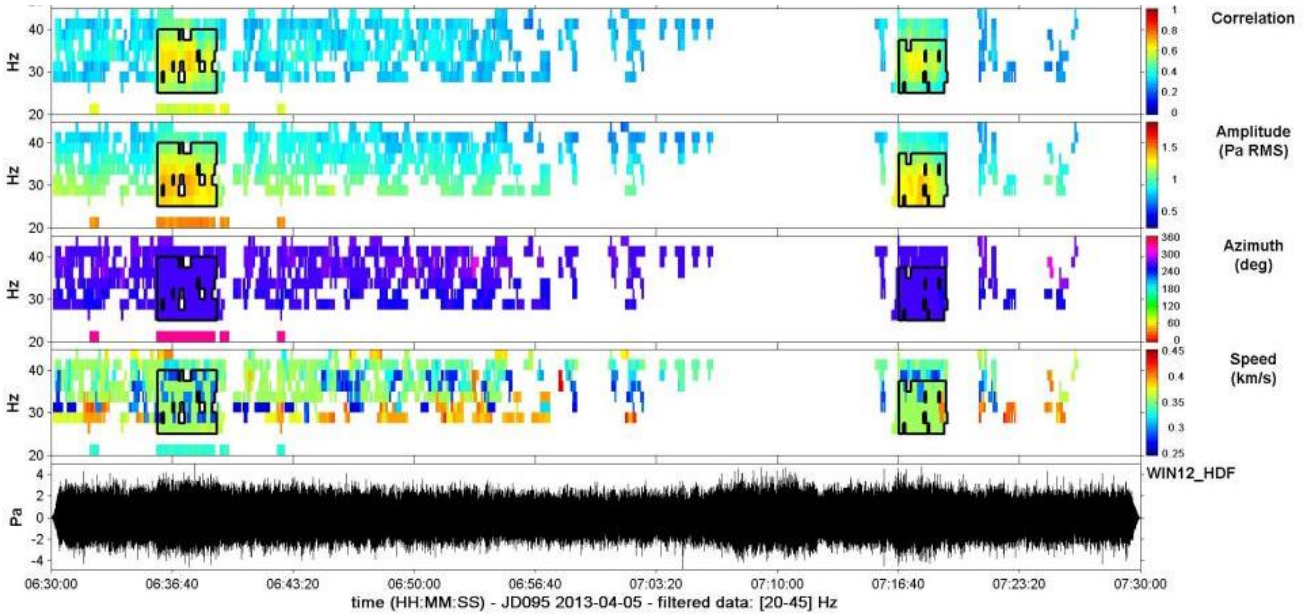


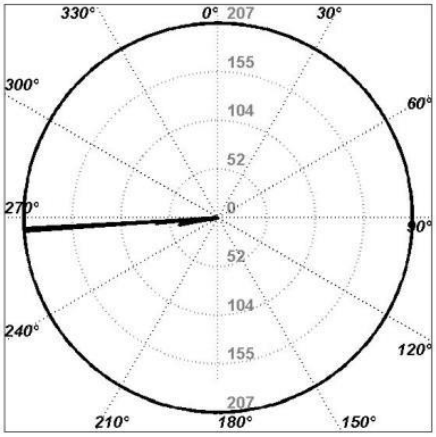
JD095 2013-04-05 : 06:35:58 => 06:38:03

75 pixels

Speed = 0.294 +/- 0.028 km/s
Azimuth = 262.6 +/- 3.8 deg
Frequency = 31.111 +/- 1.827 Hz
Amplitude = 0.953 +/- 0.045 Pa RMS

Figure A2-40



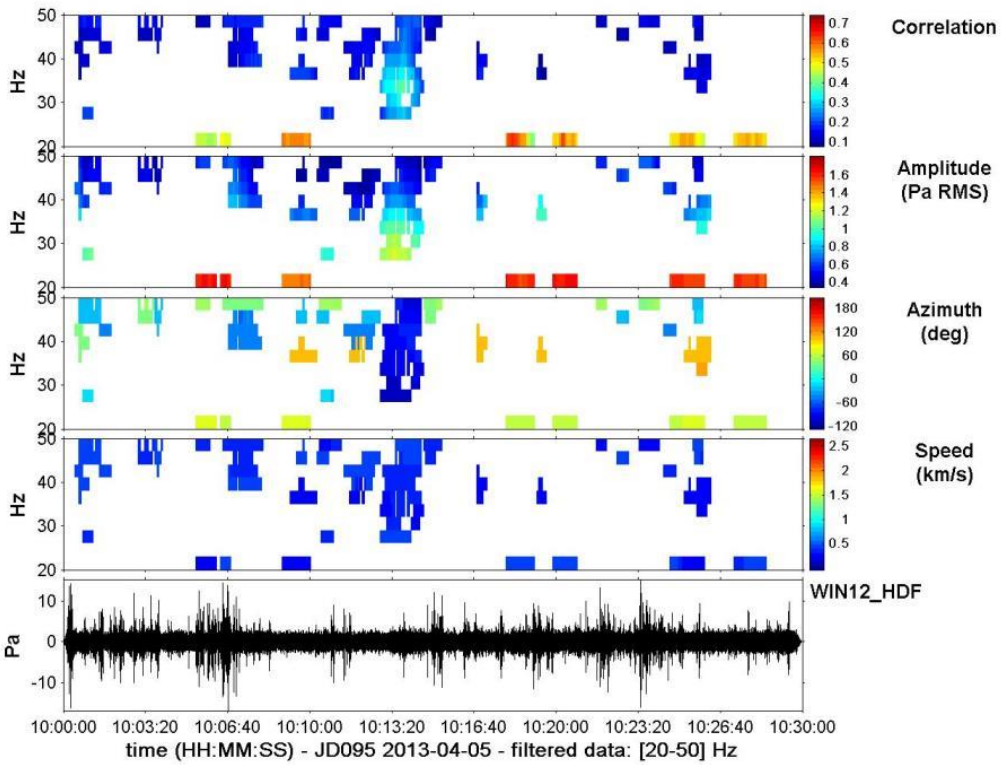


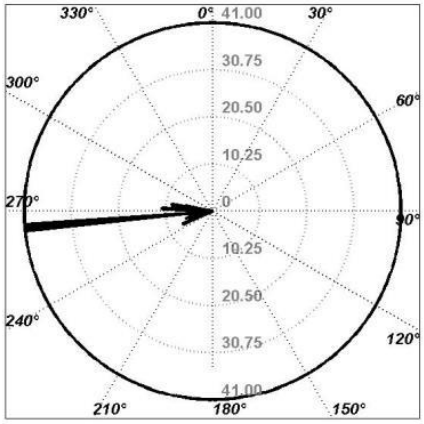
JD095 2013-04-05 : 06:35:53 => 07:19:23

357 pixels

Speed = 0.344 +/- 0.030 km/s
Azimuth = 265.1 +/- 3.0 deg
Frequency = 31.889 +/- 4.499 Hz
Amplitude = 0.895 +/- 0.120 Pa RMS

Figure A2-41



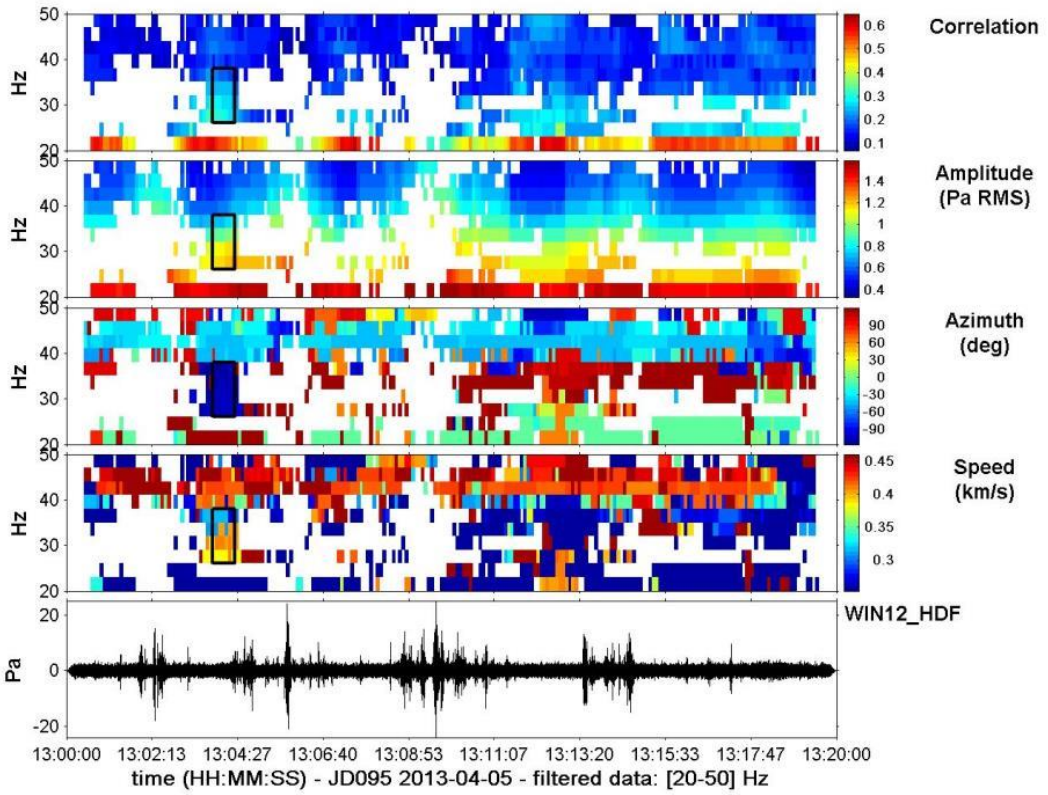


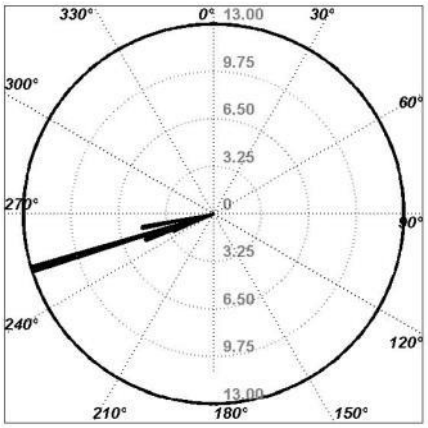
JD095 2013-04-05 : 10:12:57 => 10:14:22

102 pixels

Speed = 0.347 +/- 0.055 km/s
Azimuth = 265.8 +/- 9.4 deg
Frequency = 38.333 +/- 5.721 Hz
Amplitude = 0.611 +/- 0.148 Pa RMS

Figure A2-42





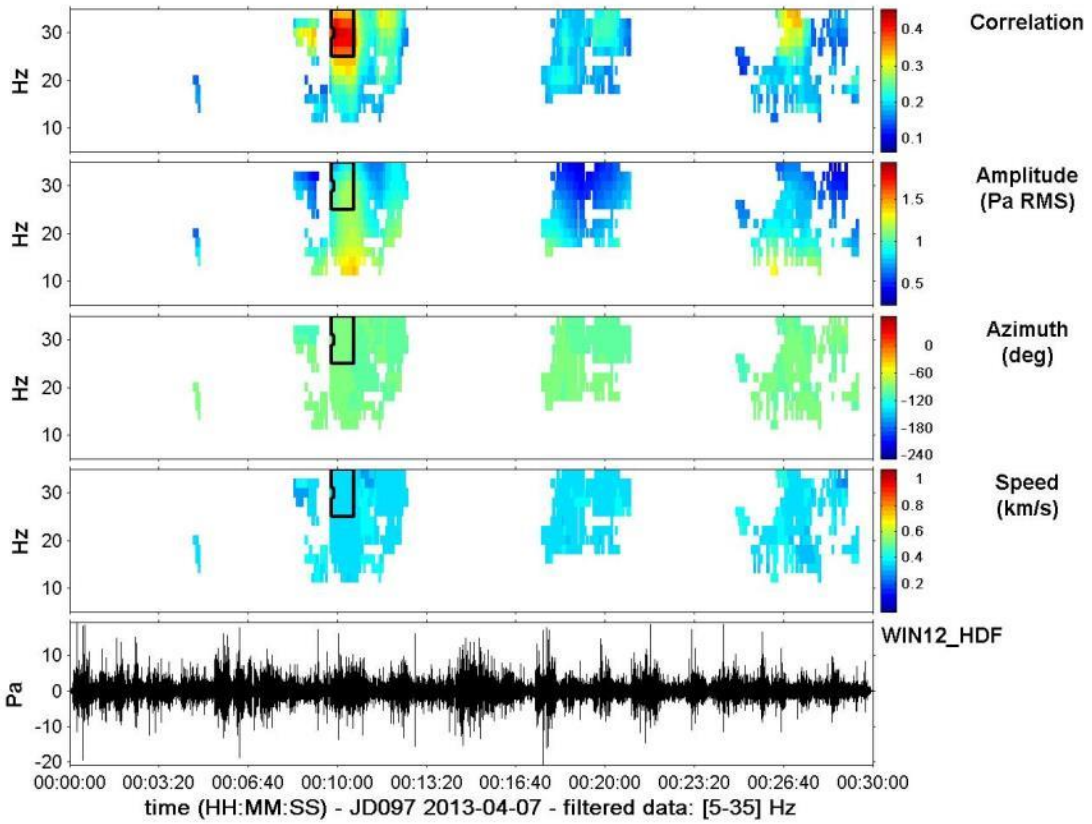
JD095 2013-04-05 : 13:03:48 => 13:04:23

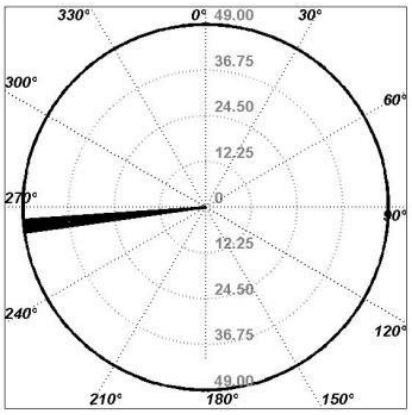
20 pixels

Speed = 0.364 +/- 0.047 km/s
Azimuth = 253.2 +/- 3.8 deg
Frequency = 31.667 +/- 3.795 Hz
Amplitude = 0.800 +/- 0.165 Pa RMS

Figure A2-43

20130407



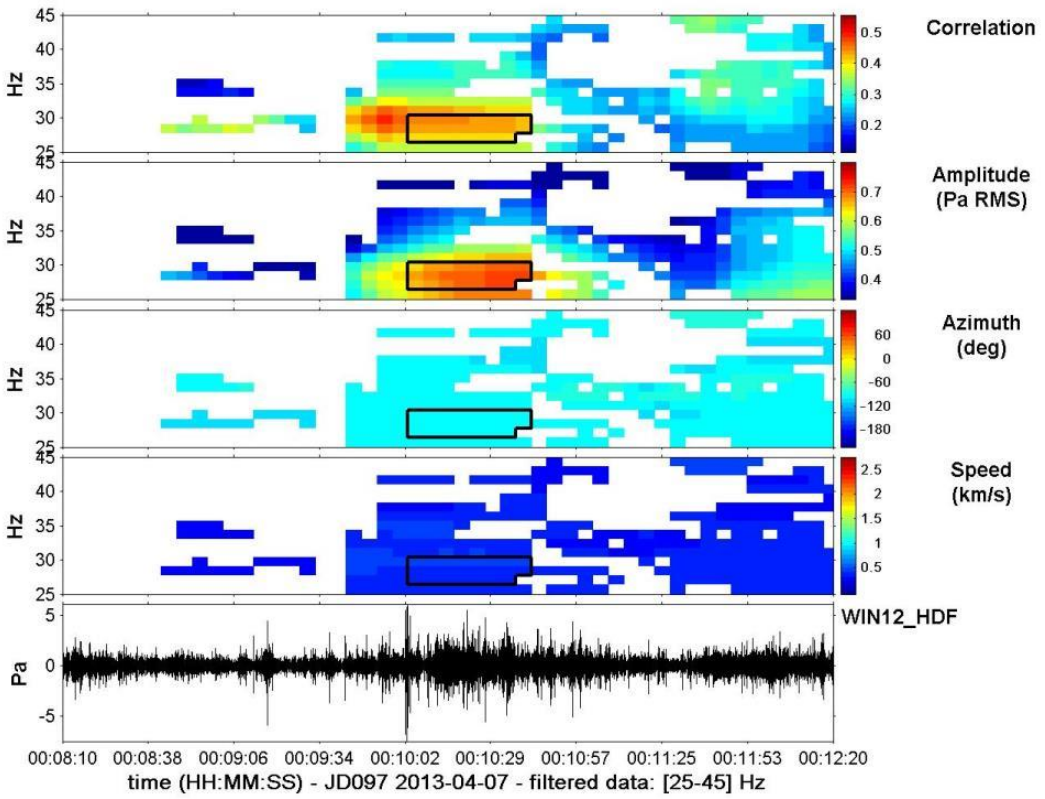


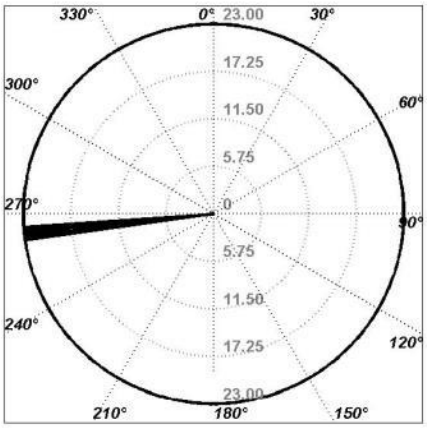
JD097 2013-04-07 : 00:09:48 => 00:10:38

49 pixels

Speed = 0.358 +/- 0.003 km/s
Azimuth = 263.9 +/- 0.2 deg
Frequency = 30.714 +/- 3.093 Hz
Amplitude = 0.685 +/- 0.097 Pa RMS

Figure A2-44



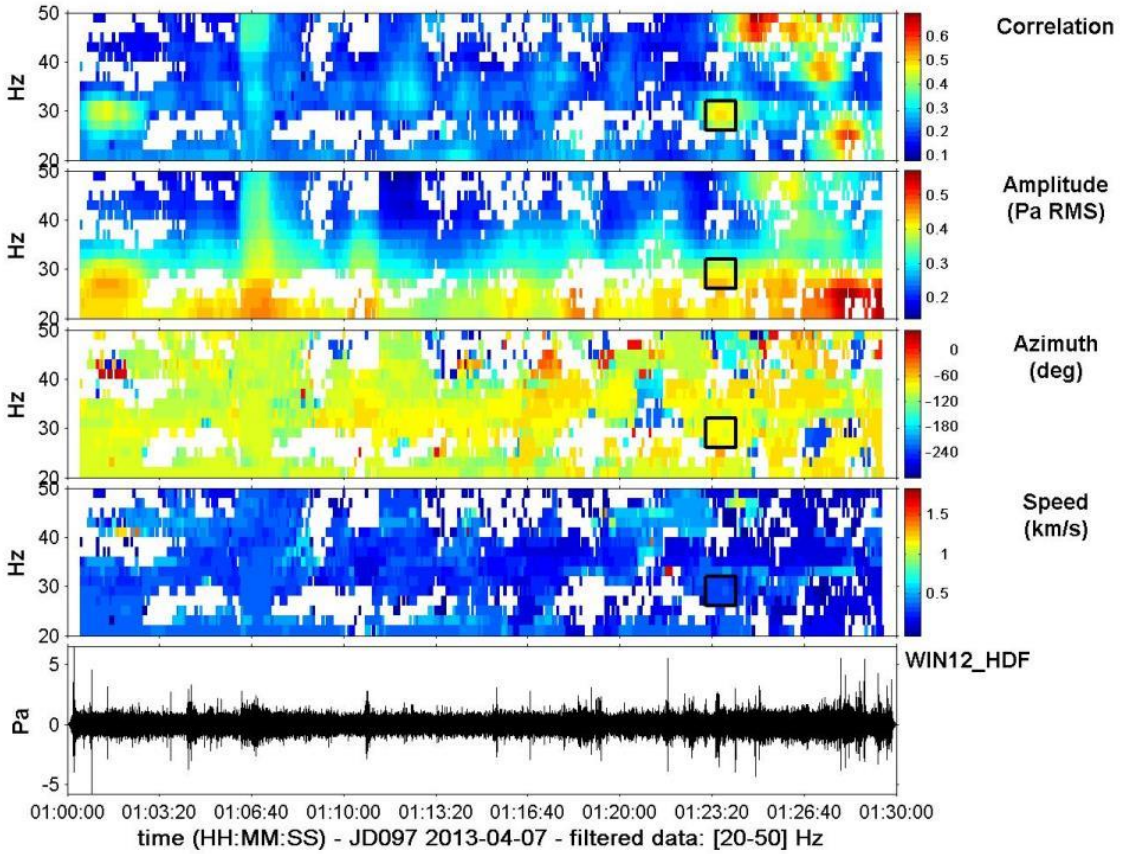


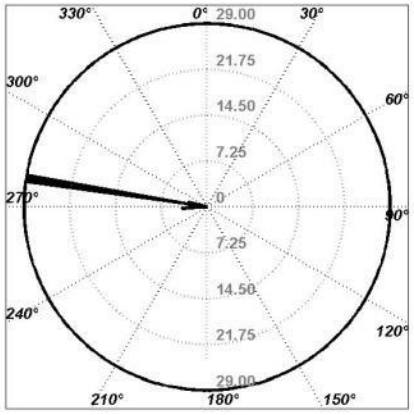
JD097 2013-04-07 : 00:10:03 => 00:10:42

23 pixels

Speed = 0.387 +/- 0.041 km/s
Azimuth = 263.3 +/- 0.7 deg
Frequency = 27.919 +/- 1.178 Hz
Amplitude = 0.662 +/- 0.025 Pa RMS

Figure A2-45



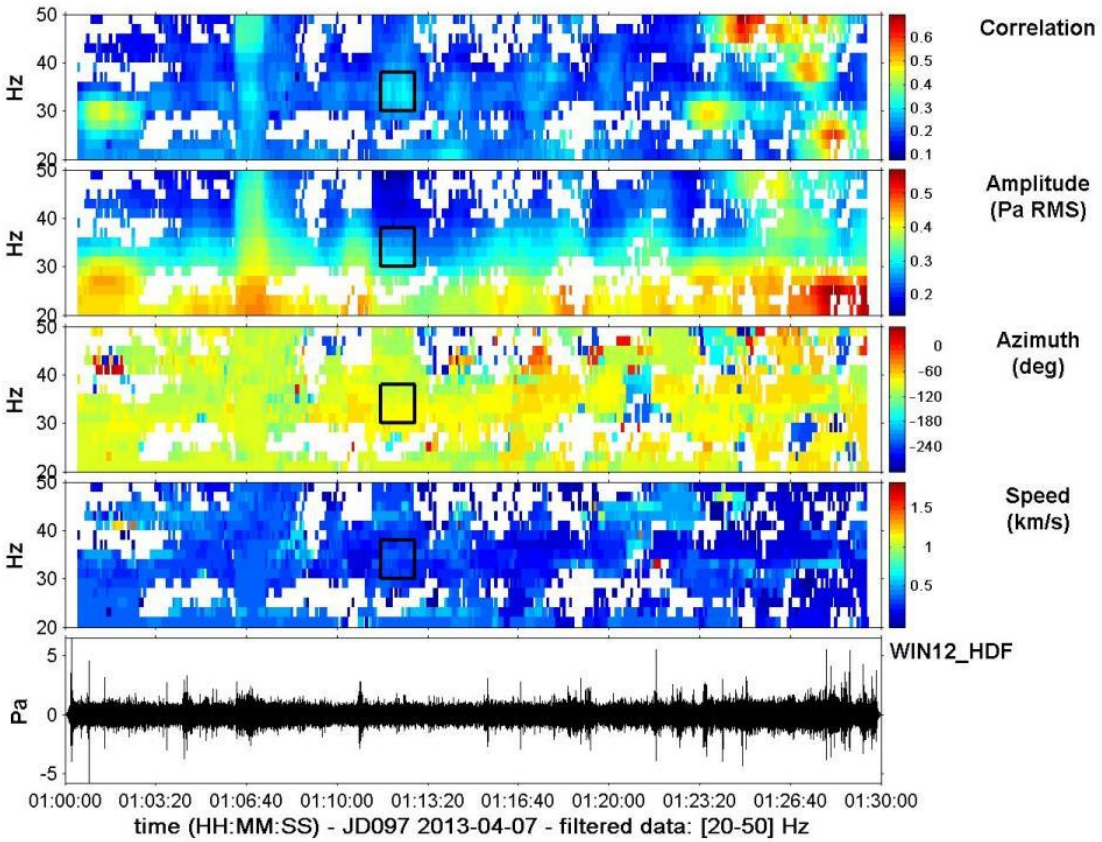


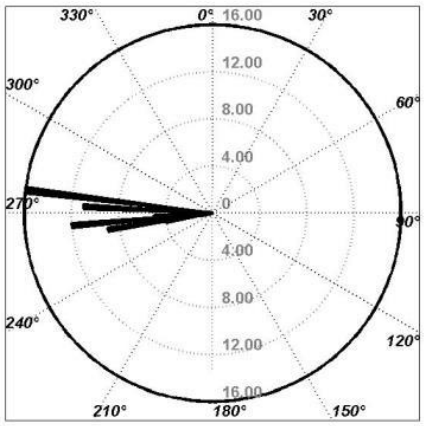
JD097 2013-04-07 : 01:23:07 => 01:24:12

39 pixels

Speed = 0.323 +/- 0.023 km/s
Azimuth = 277.9 +/- 4.3 deg
Frequency = 28.571 +/- 1.773 Hz
Amplitude = 0.337 +/- 0.028 Pa RMS

Figure A2-46





JD097 2013-04-07 : 01:11:37 => 01:12:53

60 pixels

Speed = 0.303 +/- 0.038 km/s
Azimuth = 268.9 +/- 6.6 deg
Frequency = 33.929 +/- 2.416 Hz
Amplitude = 0.211 +/- 0.017 Pa RMS

Figure A2-47

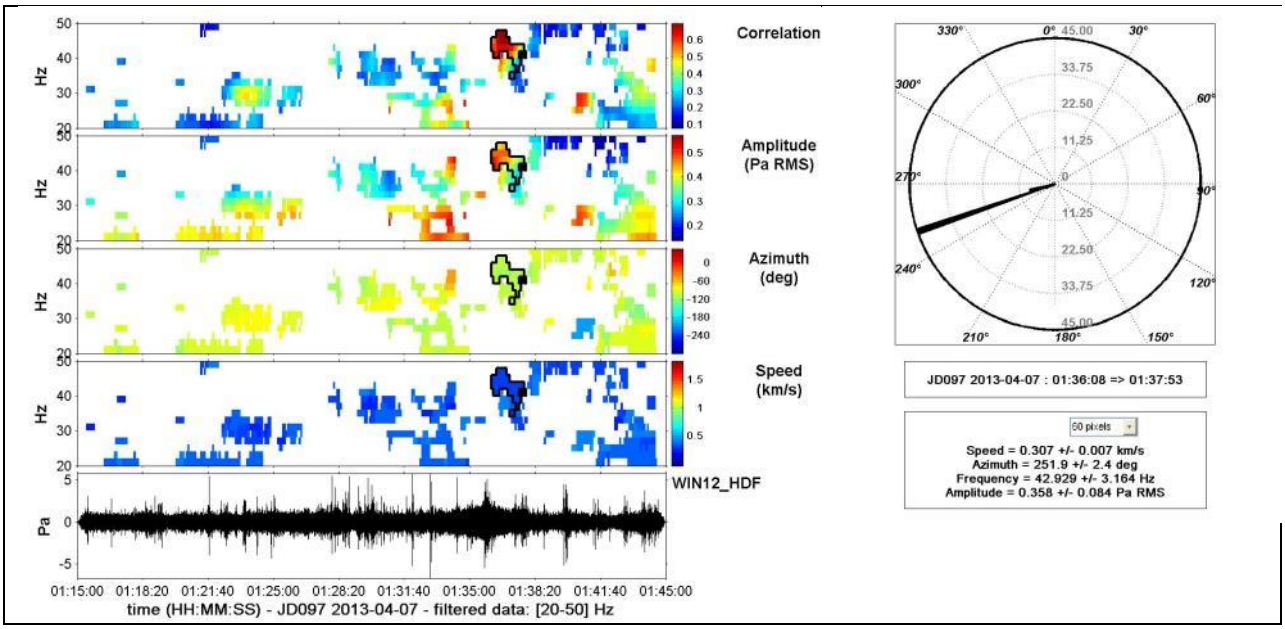
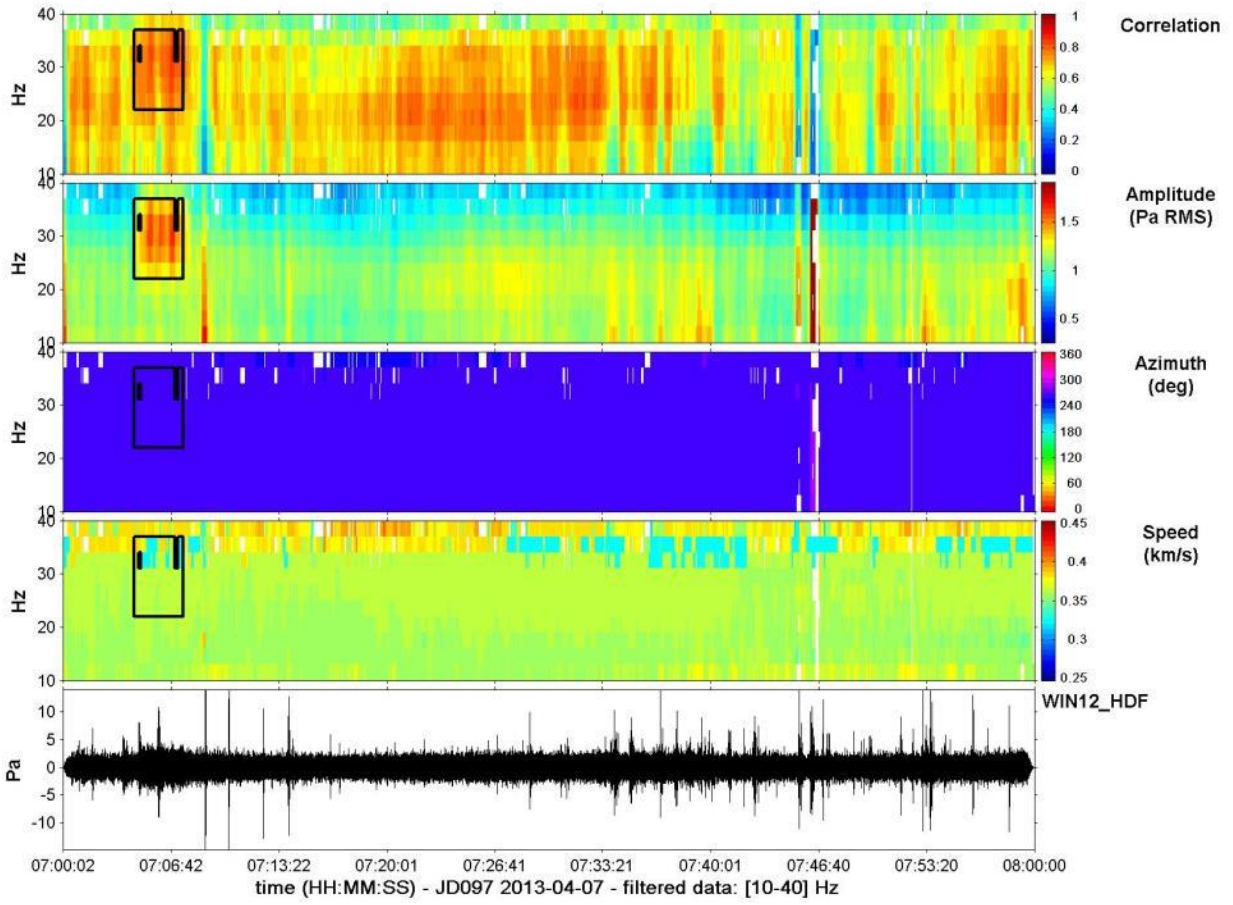

Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
01:15:00 01:18:20 01:21:40 01:25:00 01:28:20 01:31:40 01:35:00 01:38:20 01:41:40 01:45:00
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [20-50] Hz
JD097 2013-04-07 : 01:36:08 => 01:37:53
Speed = 0.307 +/- 0.007 km/s
Azimuth = 251.9 +/- 2.4 deg
Frequency = 42.929 +/- 3.164 Hz
Amplitude = 0.358 +/- 0.084 Pa RMS

Figure A2-48


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
07:00:02
07:06:42
07:13:22
07:20:01
07:26:41
07:33:21
07:40:01
07:46:40
07:53:20
08:00:00
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [10-40] Hz

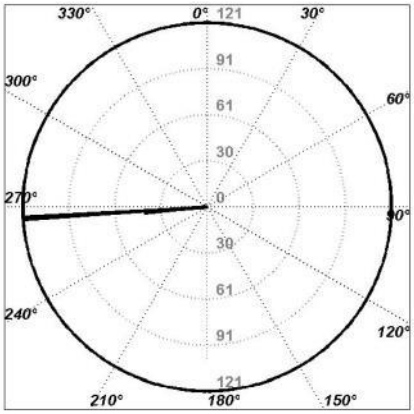
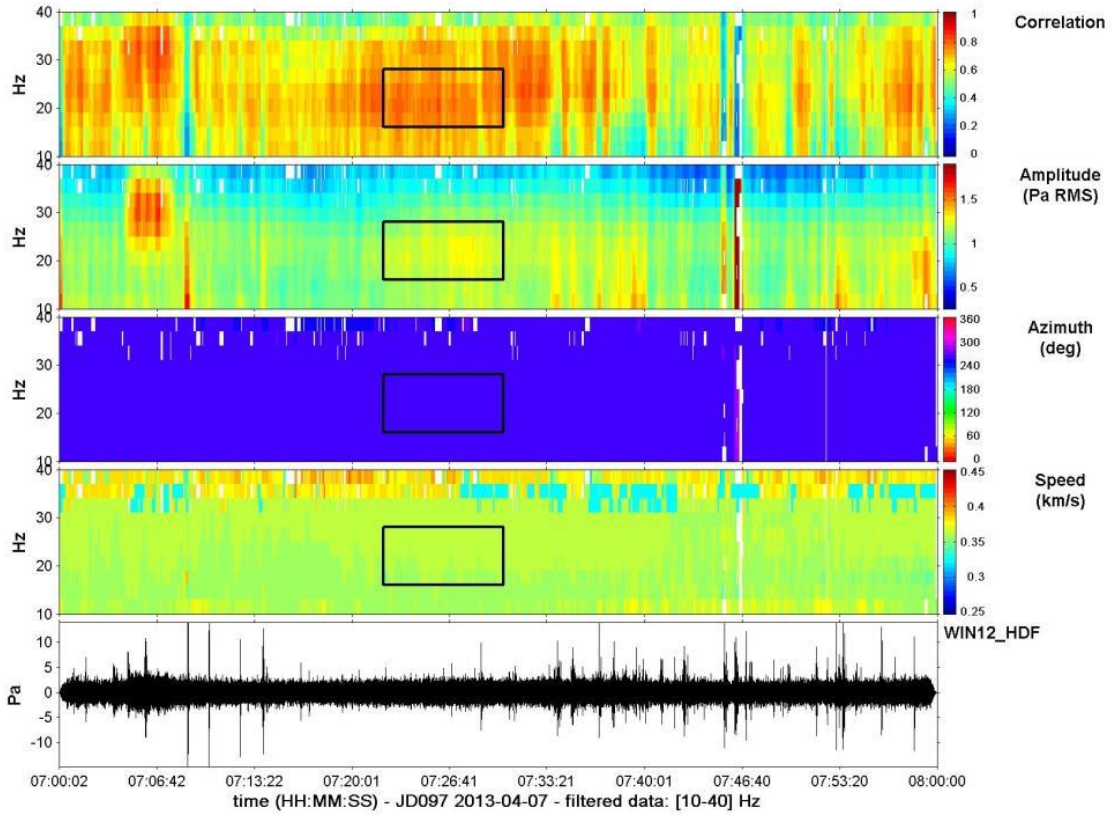
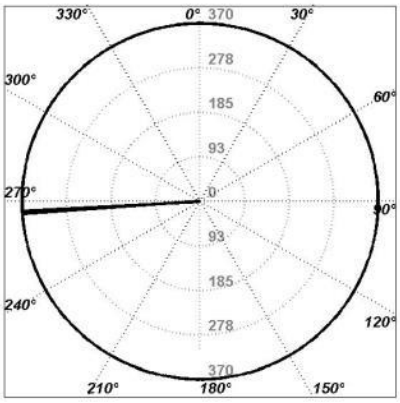

0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
JD097 2013-04-07 : 07:04:27 => 07:07:27
174 pixels
Speed = 0.357 +/- 0.015 km/s
Azimuth = 266.2 +/- 1.1 deg
Frequency = 29.847 +/- 4.725 Hz
Amplitude = 1.089 +/- 0.163 Pa RMS

Figure A2-49



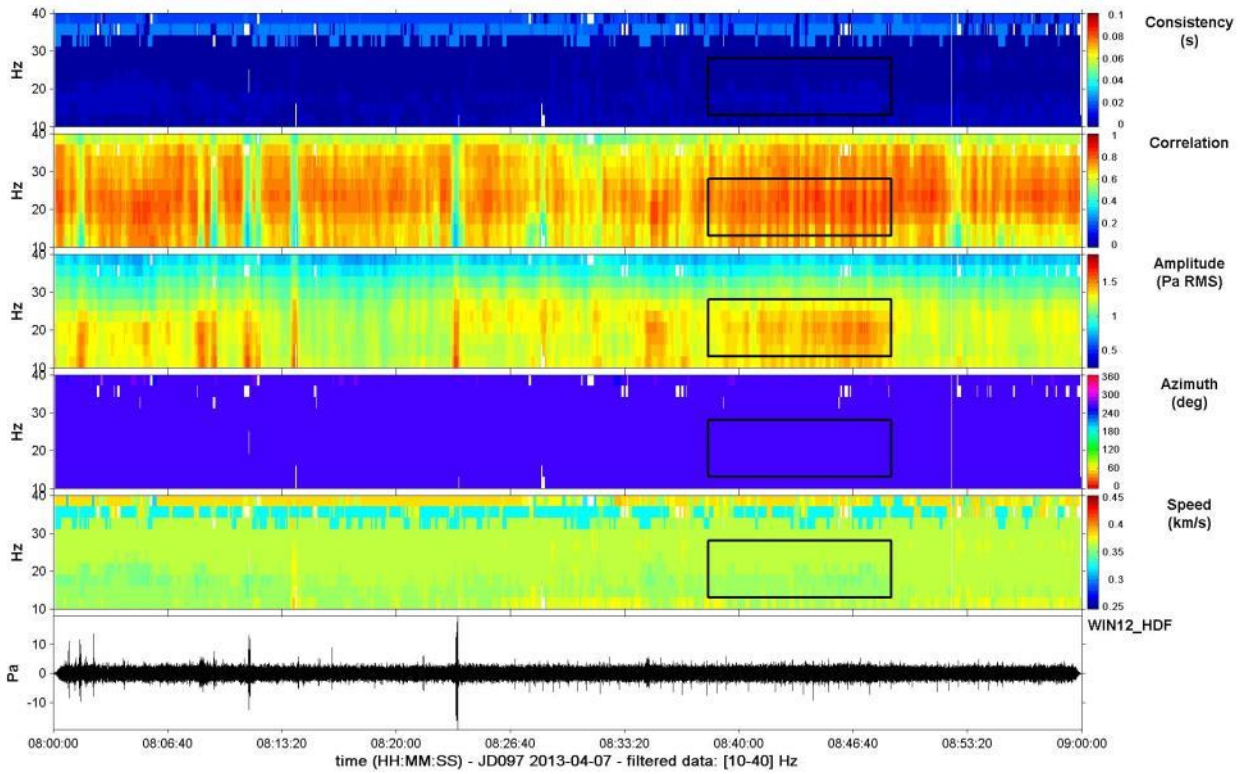


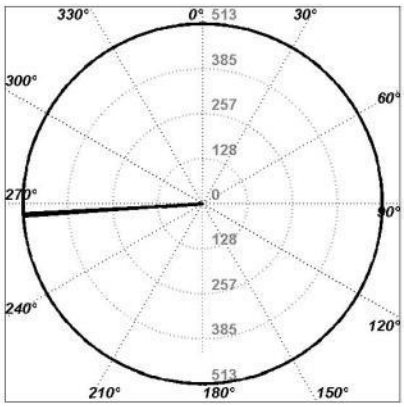
JD097 2013-04-07 : 07:22:13 => 07:30:23

392 pixels

Speed = 0.360 +/- 0.002 km/s
Azimuth = 266.8 +/- 0.2 deg
Frequency = 21.667 +/- 3.732 Hz
Amplitude = 0.850 +/- 0.049 Pa RMS

Figure A2-50



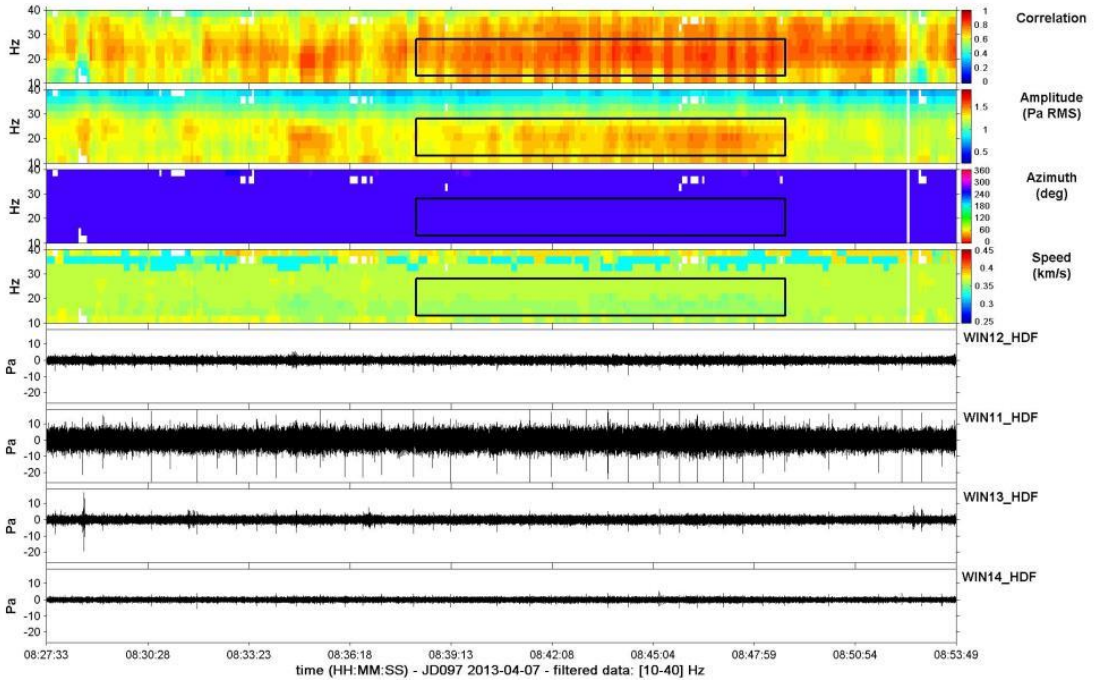


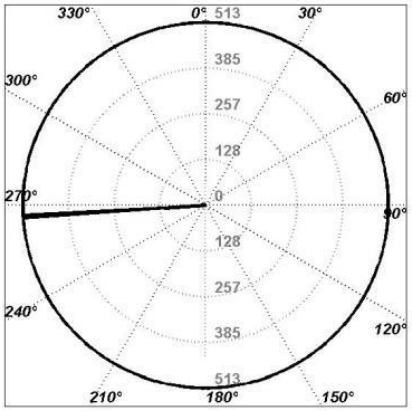
JD097 2013-04-07 : 08:38:13 => 08:48:53

640 pixels

Speed = 0.359 +/- 0.003 km/s
Azimuth = 266.5 +/- 0.5 deg
Frequency = 20.000 +/- 4.718 Hz
Amplitude = 1.020 +/- 0.087 Pa RMS

Figure A2-51



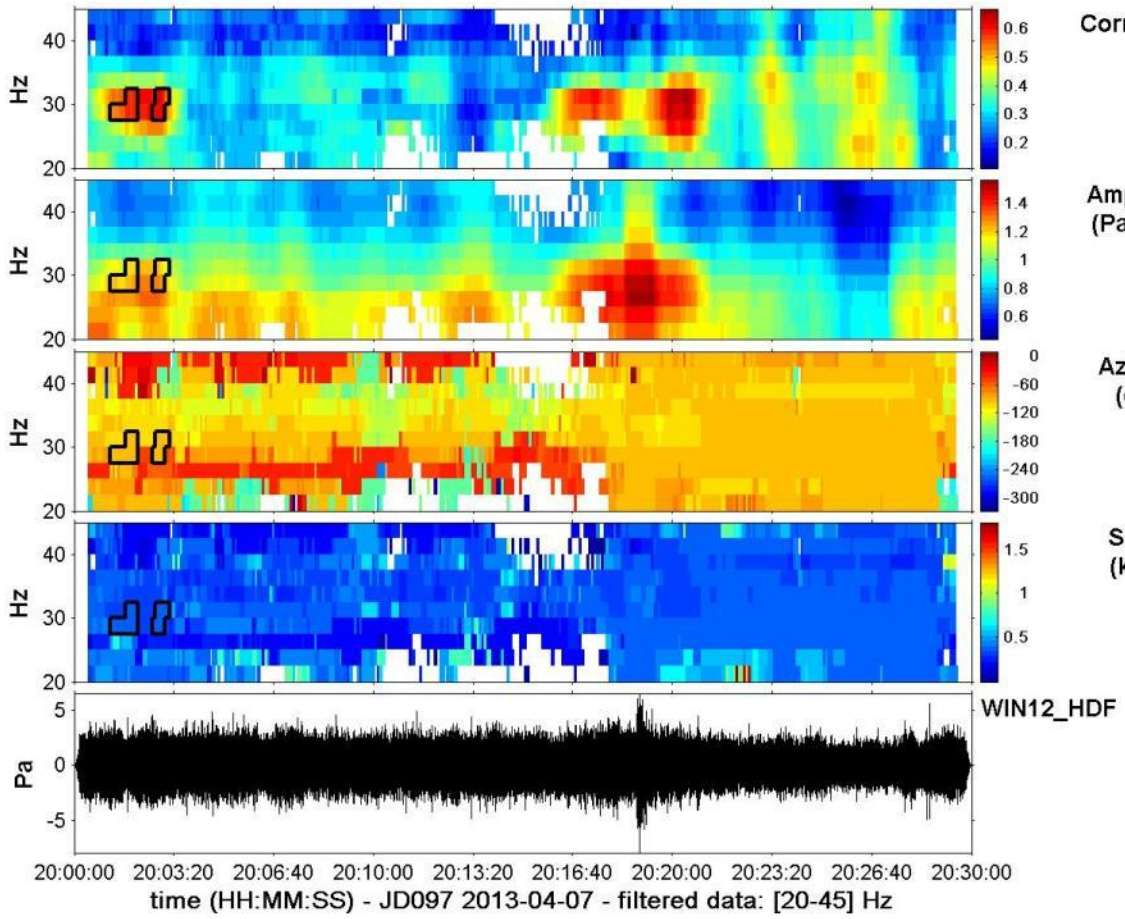


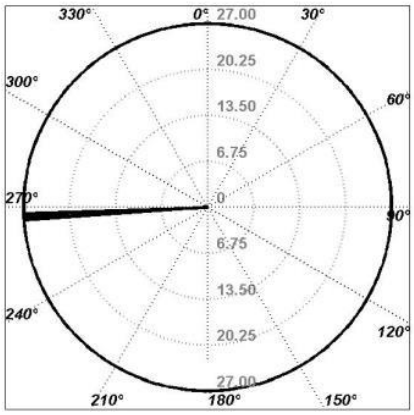
JD097 2013-04-07 : 08:38:13 => 08:48:53

640 pixels

Speed = 0.359 +/- 0.003 km/s
Azimuth = 266.5 +/- 0.5 deg
Frequency = 20.000 +/- 4.718 Hz
Amplitude = 1.020 +/- 0.087 Pa RMS

Figure A2-52



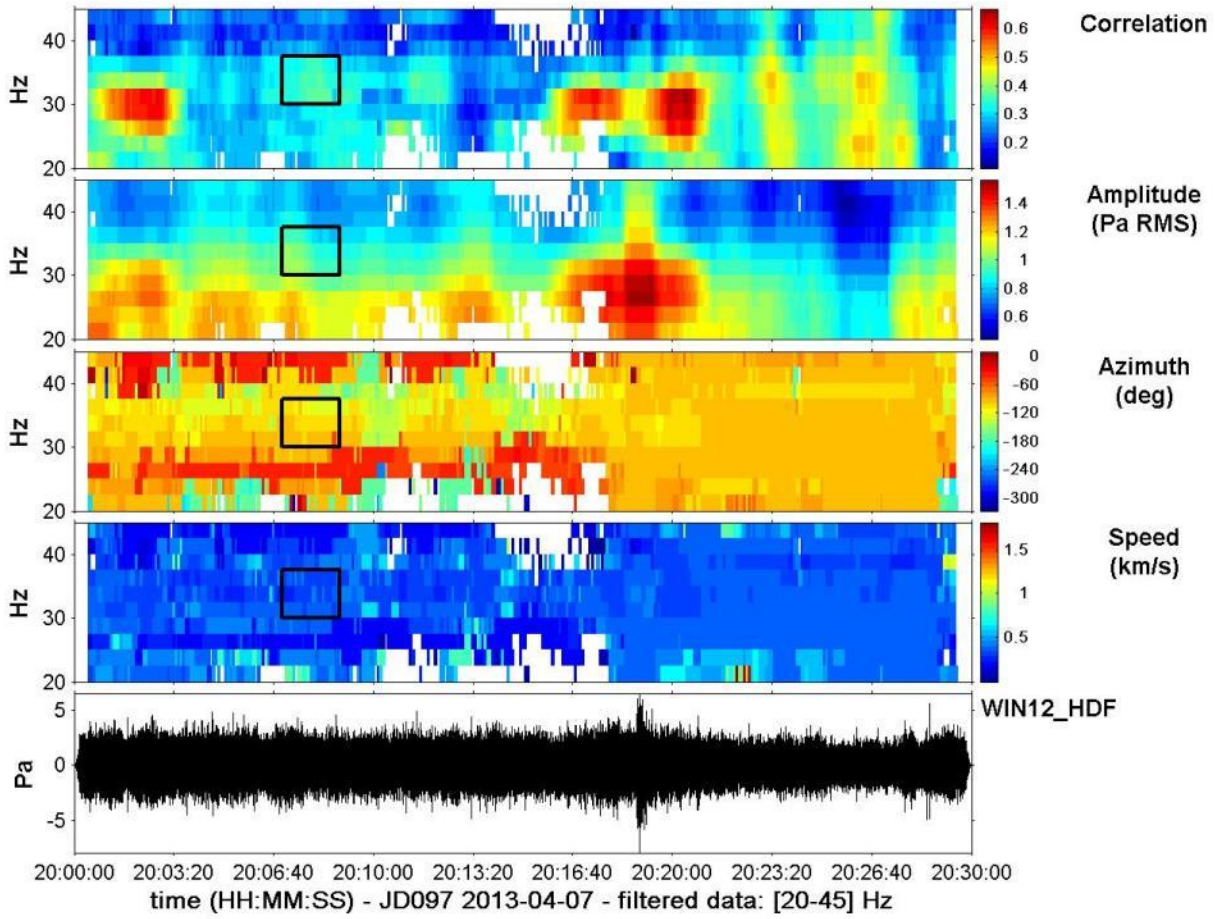


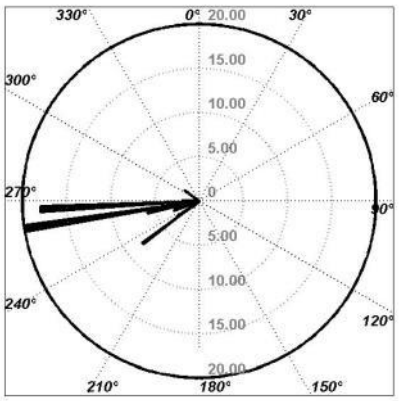
JD097 2013-04-07 : 20:01:13 => 20:03:13

27 pixels

Speed = 0.378 +/- 0.000 km/s
Azimuth = 267.9 +/- 0.0 deg
Frequency = 29.465 +/- 1.391 Hz
Amplitude = 1.062 +/- 0.054 Pa RMS

Figure A2-53



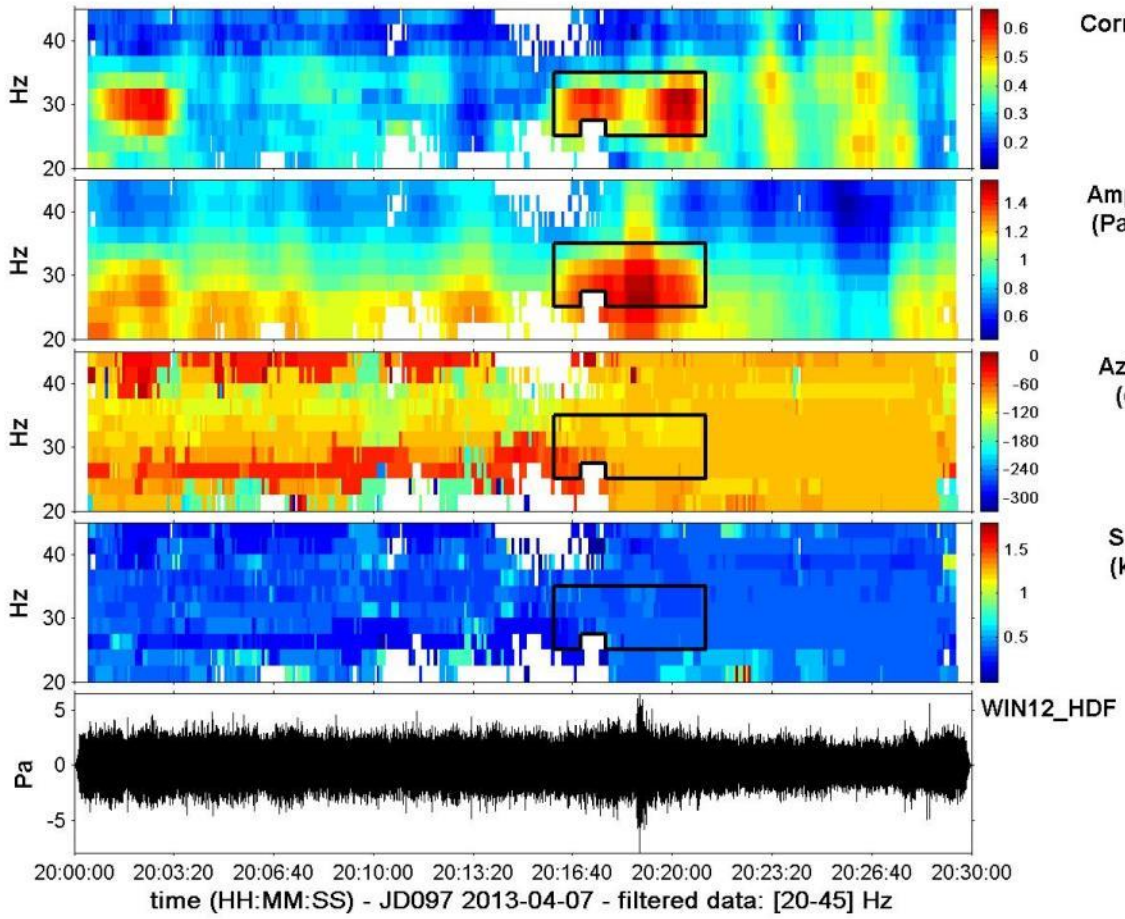


JD097 2013-04-07 : 20:06:58 => 20:08:53

69 pixels

Speed = 0.337 +/- 0.043 km/s
Azimuth = 257.7 +/- 14.4 deg
Frequency = 33.889 +/- 2.285 Hz
Amplitude = 0.779 +/- 0.066 Pa RMS

Figure A2-54


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
20:00:00 20:03:20 20:06:40 20:10:00 20:13:20 20:16:40 20:20:00 20:23:20 20:26:40 20:30:00
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [20-45] Hz

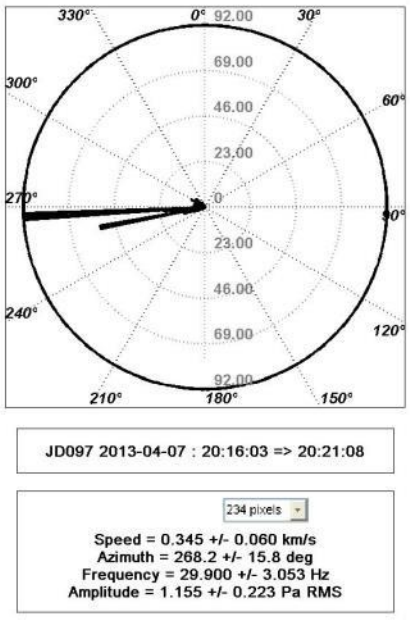
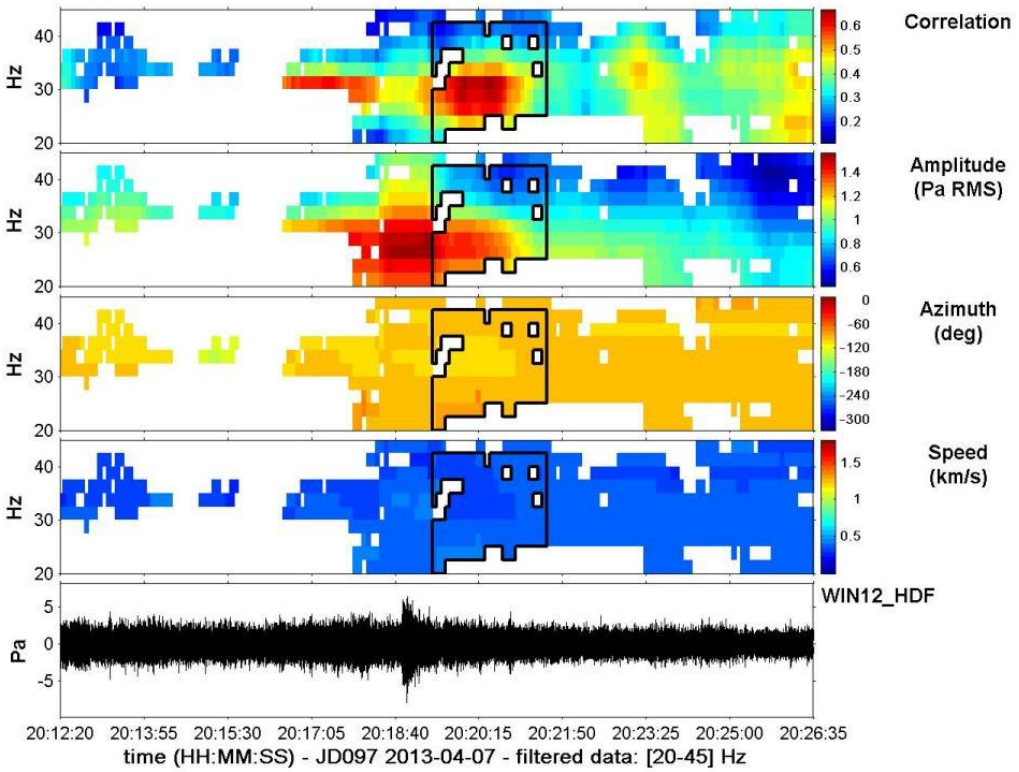
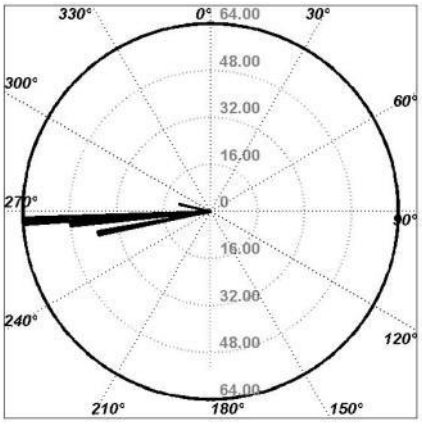

JD097 2013-04-07 : 20:16:03 => 20:21:08
234 pixels
Speed = 0.345 +/- 0.060 km/s
Azimuth = 268.2 +/- 15.8 deg
Frequency = 29.900 +/- 3.053 Hz
Amplitude = 1.155 +/- 0.223 Pa RMS

Figure A2-55



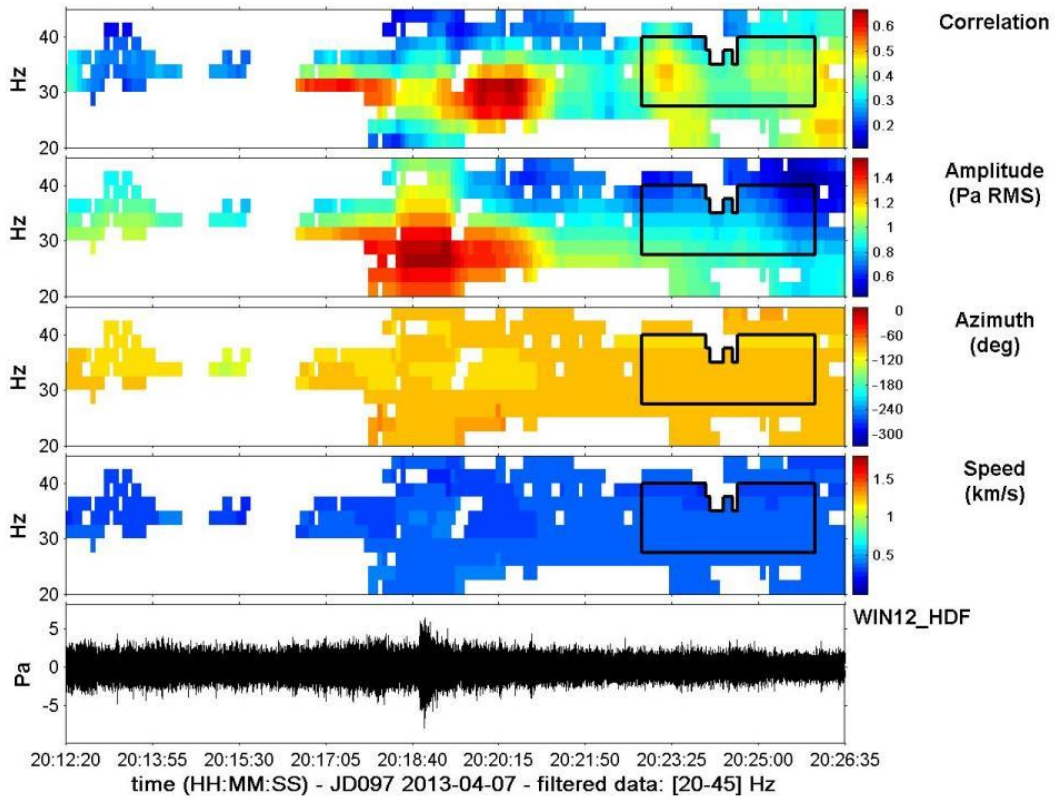


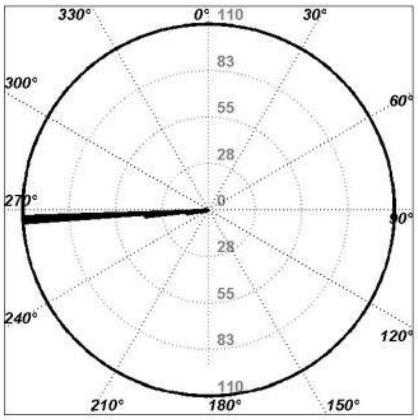
JD097 2013-04-07 : 20:19:23 => 20:21:33

182 pixels

Speed = 0.349 +/- 0.039 km/s
Azimuth = 265.5 +/- 5.6 deg
Frequency = 32.546 +/- 6.422 Hz
Amplitude = 0.911 +/- 0.266 Pa RMS

Figure A2-56



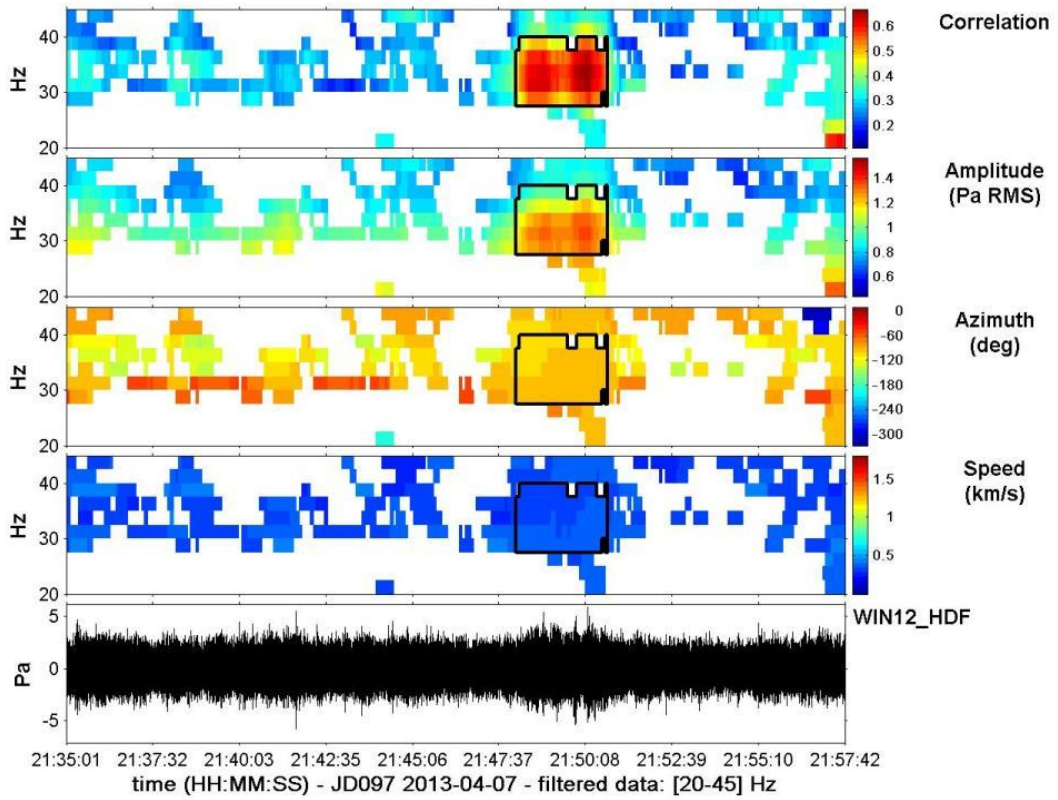


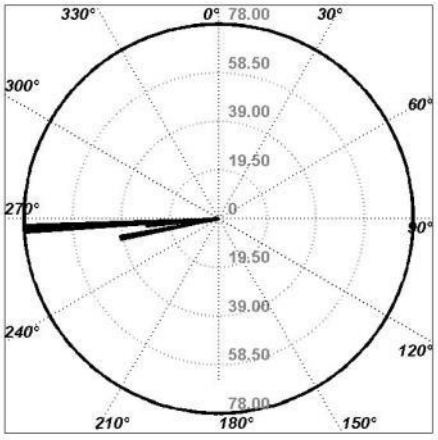
JD097 2013-04-07 : 20:22:53 => 20:26:03

179 pixels

Speed = 0.351 +/- 0.028 km/s
Azimuth = 264.9 +/- 3.4 deg
Frequency = 33.610 +/- 3.874 Hz
Amplitude = 0.656 +/- 0.083 Pa RMS

Figure A2-57



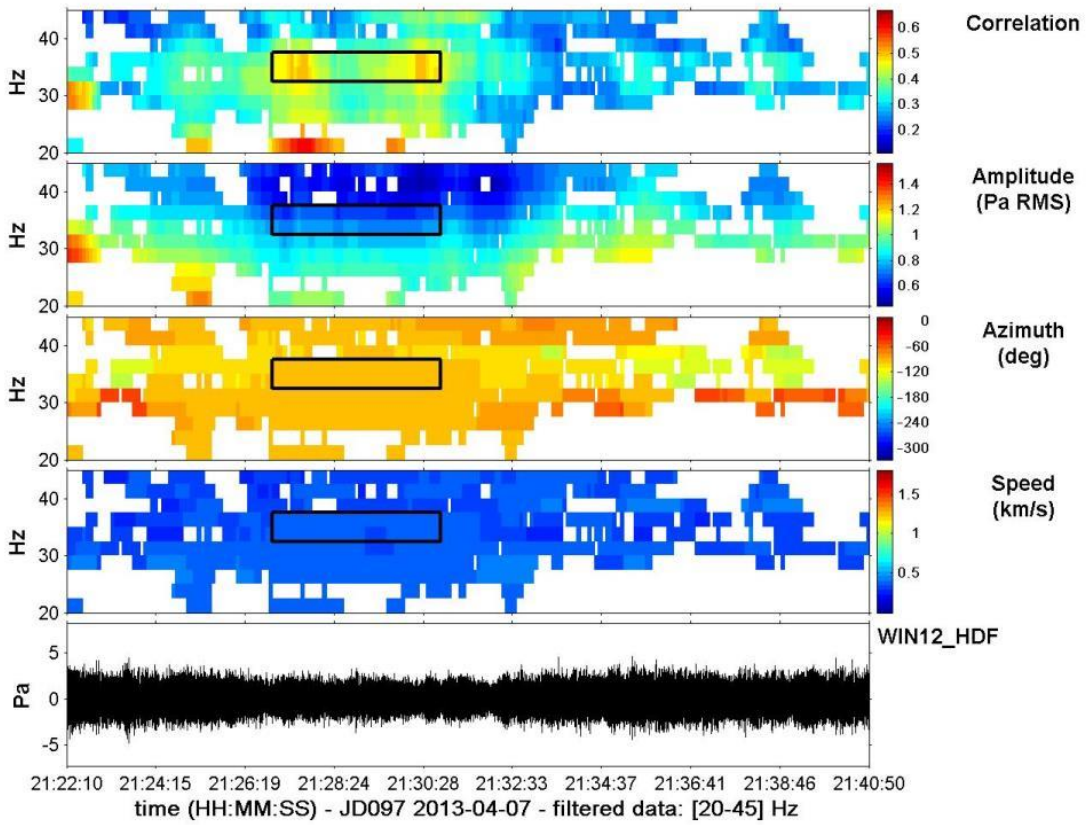


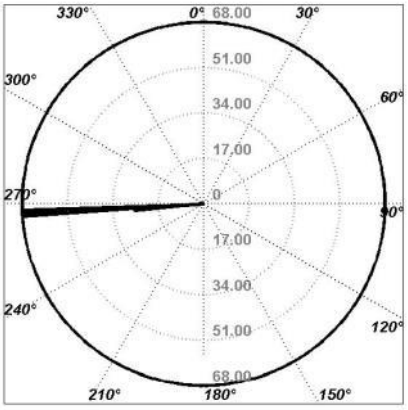
JD097 2013-04-07 : 21:48:08 => 21:50:48

152 pixels

Speed = 0.333 +/- 0.034 km/s
Azimuth = 264.3 +/- 3.3 deg
Frequency = 33.670 +/- 3.830 Hz
Amplitude = 1.051 +/- 0.140 Pa RMS

Figure A2-58



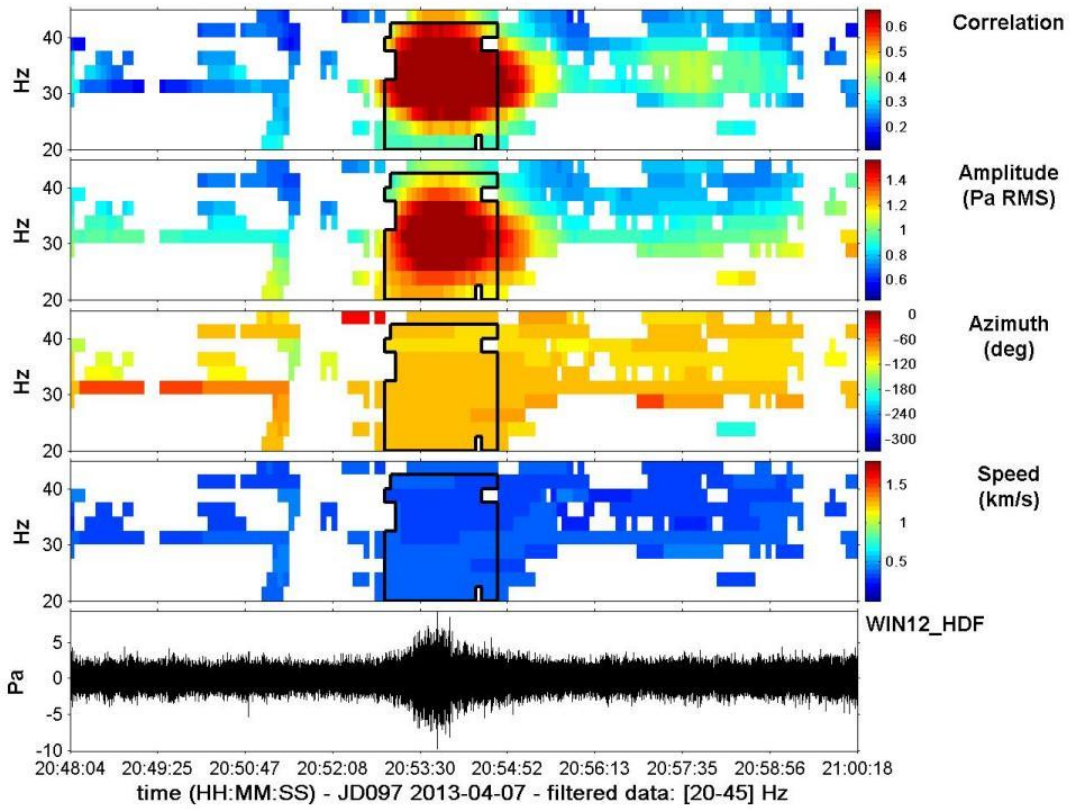


JD097 2013-04-07 : 21:26:58 => 21:30:53

94 pixels

Speed = 0.356 +/- 0.017 km/s
Azimuth = 266.3 +/- 0.5 deg
Frequency = 35.278 +/- 1.396 Hz
Amplitude = 0.592 +/- 0.032 Pa RMS

Figure A2-59


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
20:48:04 20:49:25 20:50:47 20:52:08 20:53:30 20:54:52 20:56:13 20:57:35 20:58:56 21:00:18
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [20-45] Hz

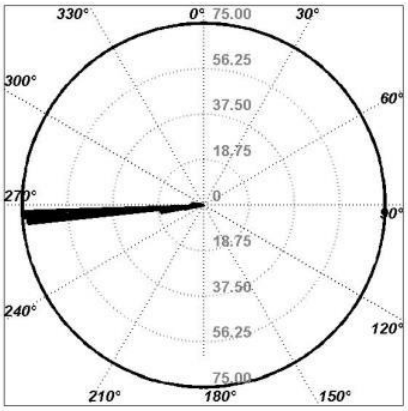
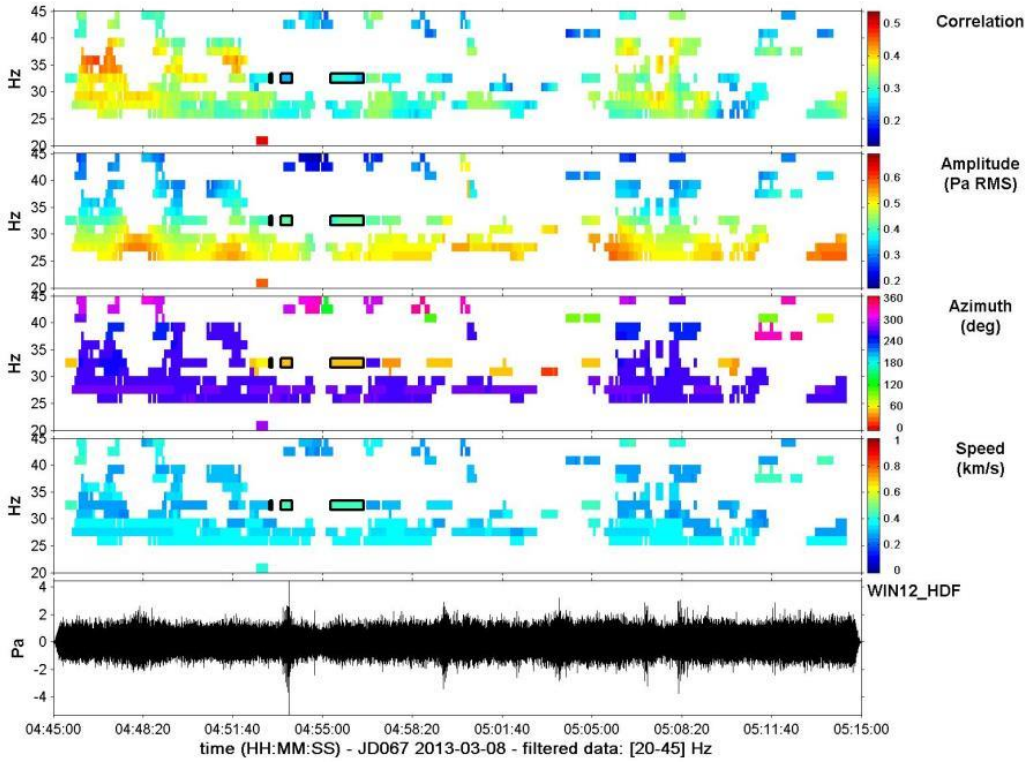

0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
75.00
56.25
37.50
18.75
0
JD097 2013-04-07 : 20:52:58 => 20:54:43
180 pixels
Speed = 0.340 +/- 0.036 km/s
Azimuth = 265.4 +/- 3.0 deg
Frequency = 30.880 +/- 7.161 Hz
Amplitude = 1.375 +/- 0.347 Pa RMS

Figure A2-60

Appendix 2b: Array 1– Other examples of signals at Array 1 for select dates and time segments, coming from directions other than 270 degrees (the likely source of 30 – 35 Hz signals)



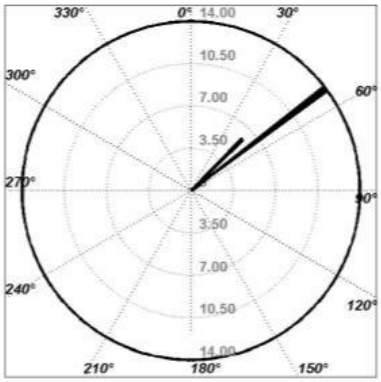
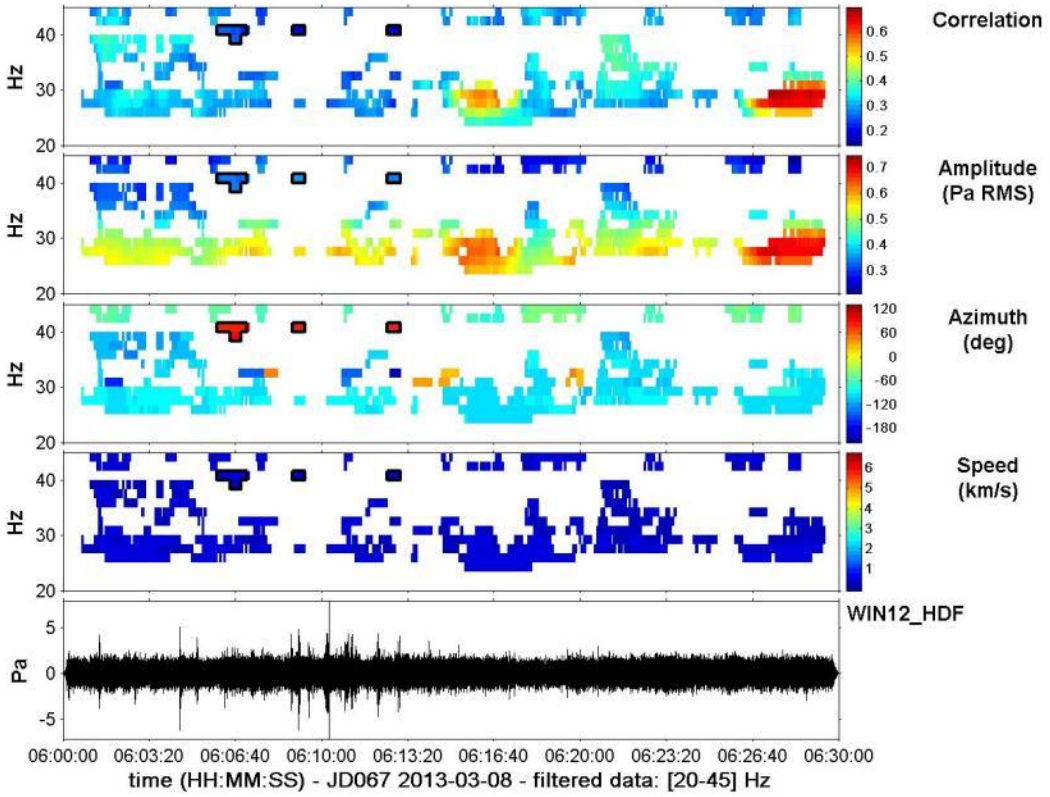
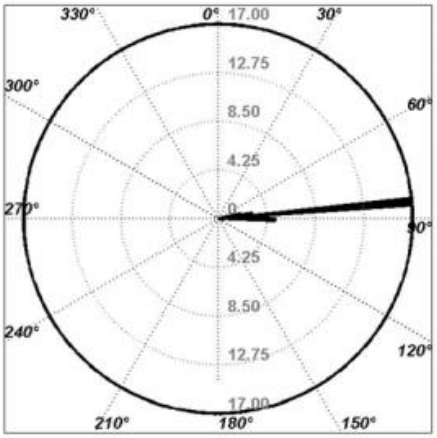


Figure A2-61



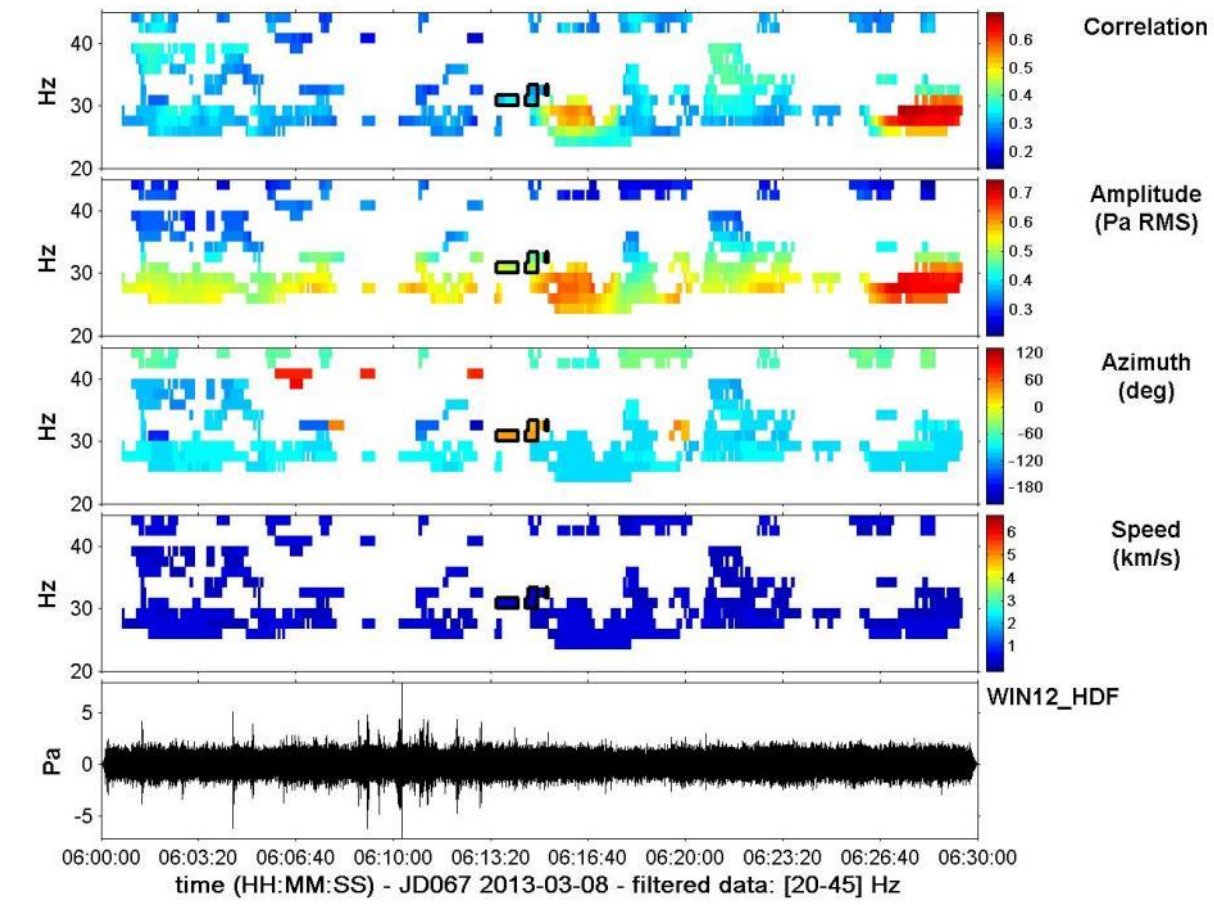


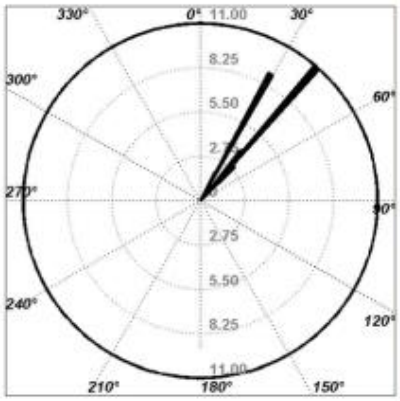
JD067 2013-03-08 : 06:05:58 => 06:13:03

31 pixels

Speed = 0.328 +/- 0.026 km/s
Azimuth = 85.3 +/- 3.8 deg
Frequency = 41.141 +/- 0.668 Hz
Amplitude = 0.291 +/- 0.006 Pa RMS

Figure A2-62


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
06:00:00 06:03:20 06:06:40 06:10:00 06:13:20 06:16:40 06:20:00 06:23:20 06:26:40 06:30:00
time (HH:MM:SS) - JD067 2013-03-08 - filtered data: [20-45] Hz


JD067 2013-03-08 : 06:13:33 => 06:20:08
Speed = 0.372 +/- 0.031 km/s
Azimuth = 36.1 +/- 6.0 deg
Frequency = 31.369 +/- 0.875 Hz
Amplitude = 0.432 +/- 0.028 Pa RMS

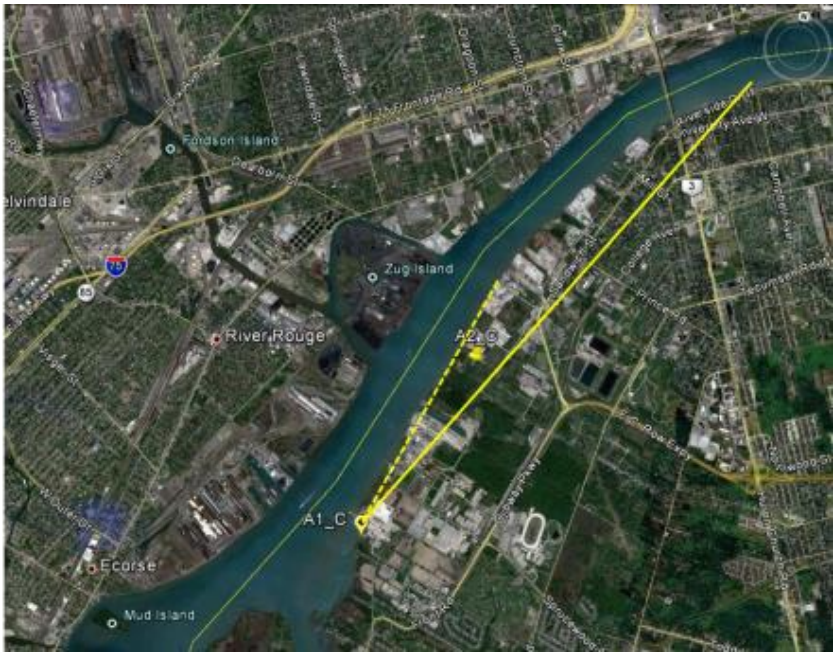
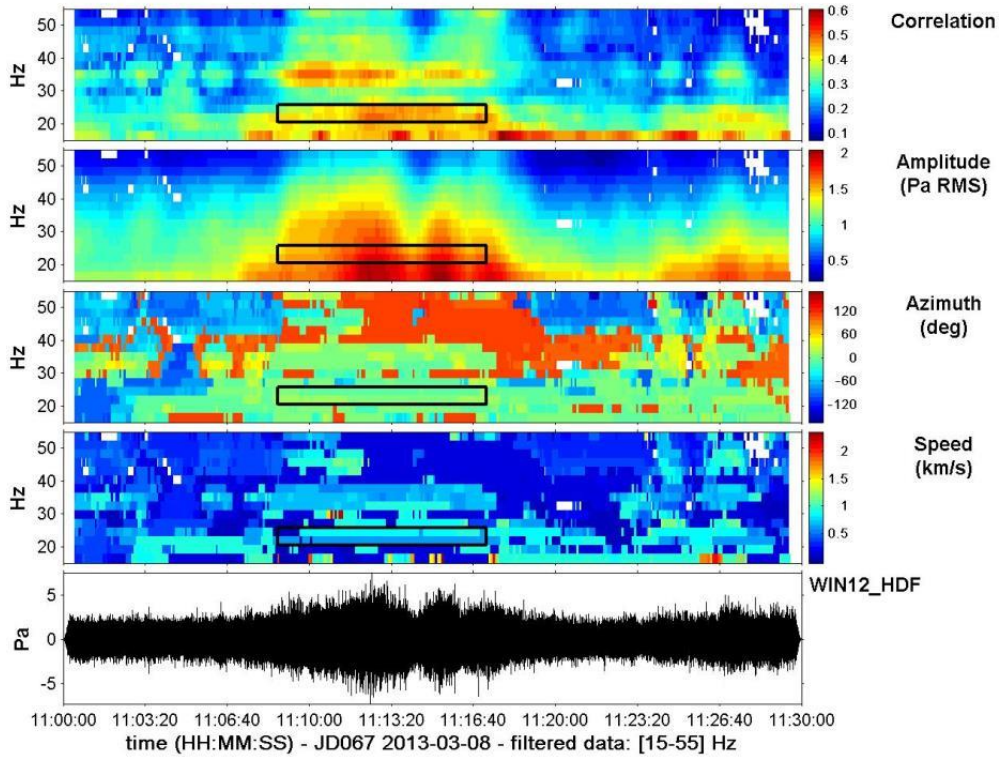
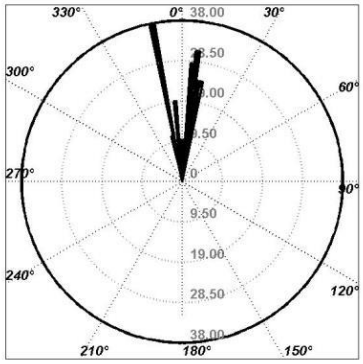

Ford on Island
Zug Island
River Rouge
A2_C
A1_C
Ecorse
Mud Island

Figure A2-63



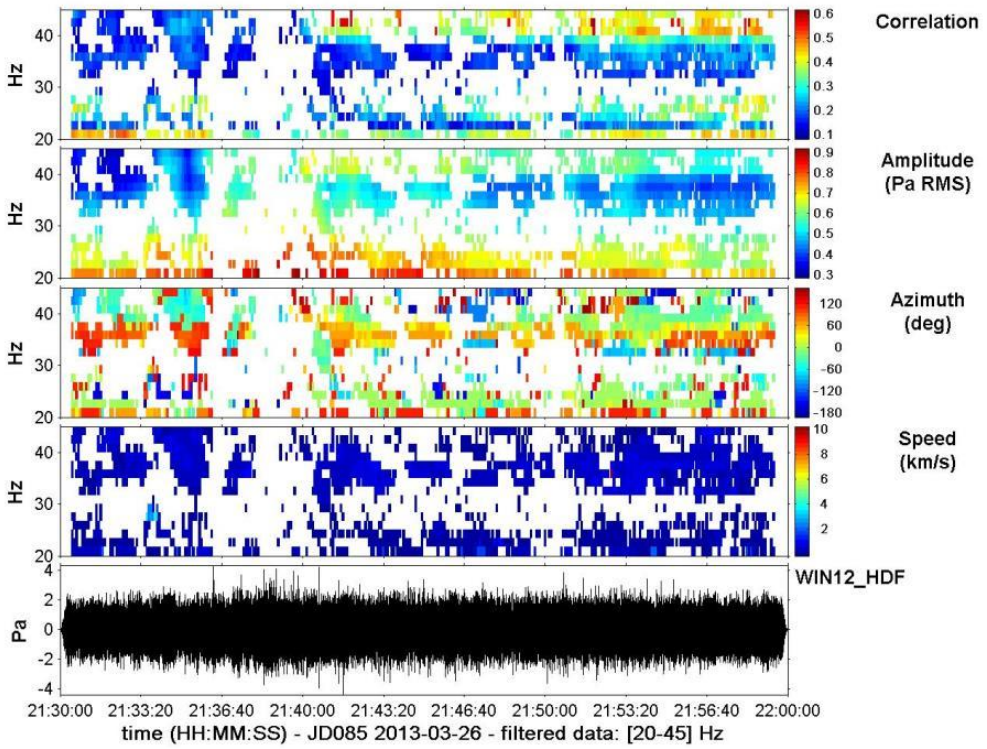


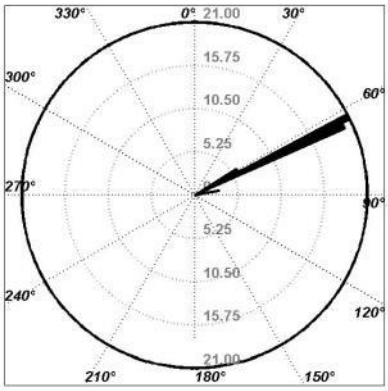
JD067 2013-03-08 : 11:08:43 => 11:17:13

204 pixels

Speed = 0.695 +/- 0.200 km/s
Azimuth = 0.7 +/- 8.2 deg
Frequency = 22.143 +/- 1.432 Hz
Amplitude = 1.323 +/- 0.205 Pa RMS

Figure A2-64



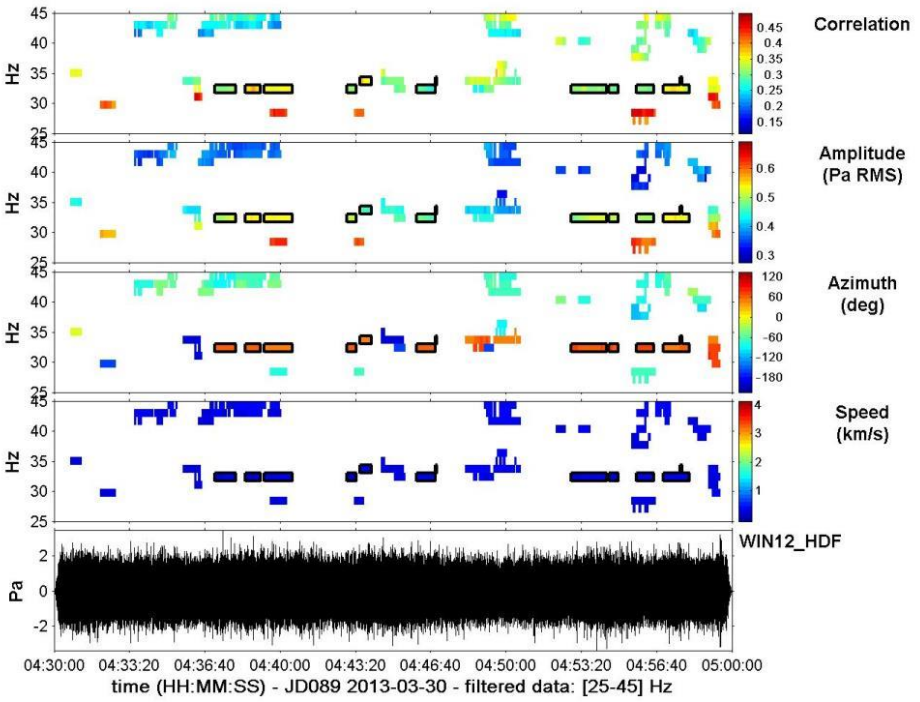


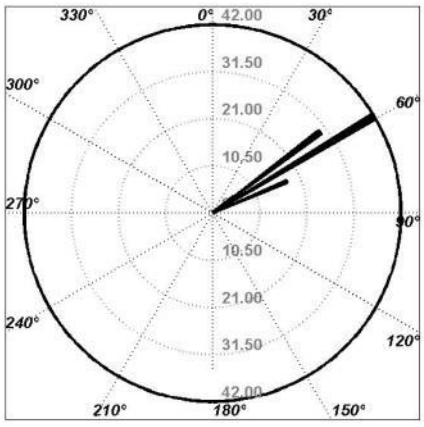
JD085 2013-03-26 : 21:41:23 => 21:52:23

57 pixels

Speed = 0.417 +/- 0.032 km/s
Azimuth = 64.2 +/- 4.2 deg
Frequency = 36.291 +/- 1.071 Hz
Amplitude = 0.426 +/- 0.040 Pa RMS

Figure A2-65



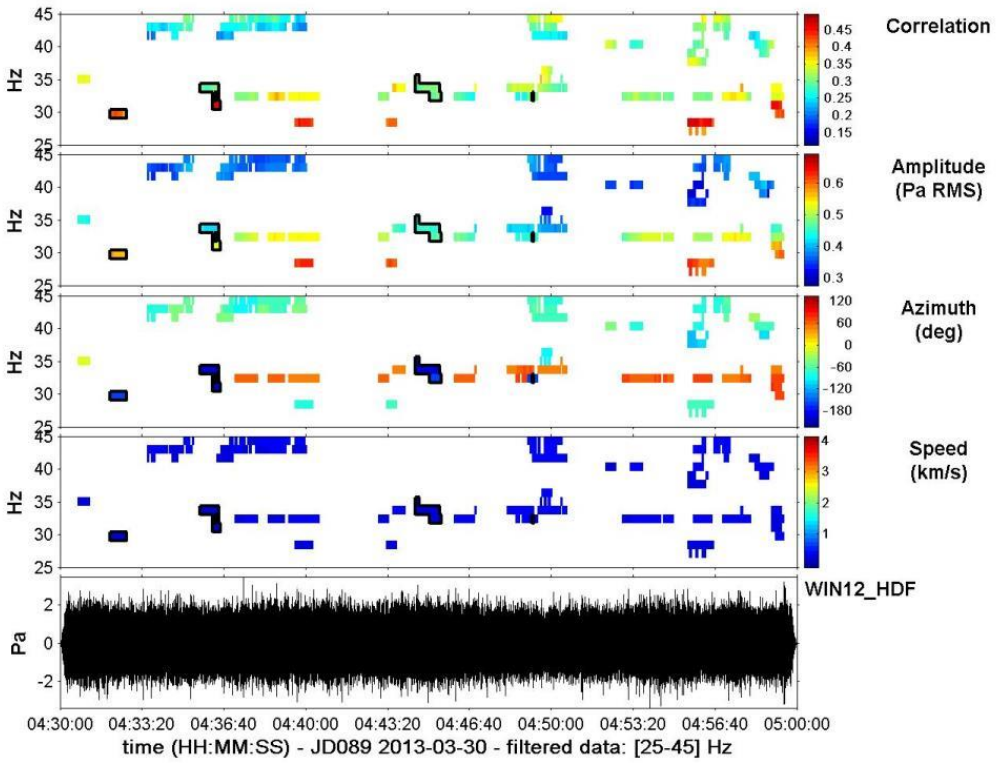


JD089 2013-03-30 : 04:37:08 => 04:58:08

104 pixels

Speed = 0.371 +/- 0.053 km/s
Azimuth = 58.2 +/- 5.1 deg
Frequency = 32.253 +/- 0.383 Hz
Amplitude = 0.466 +/- 0.029 Pa RMS

Figure A2-66


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
04:30:00 04:33:20 04:36:40 04:40:00 04:43:20 04:46:40 04:50:00 04:53:20 04:56:40 05:00:00
time (HH:MM:SS) - JD089 2013-03-30 - filtered data: [25-45] Hz

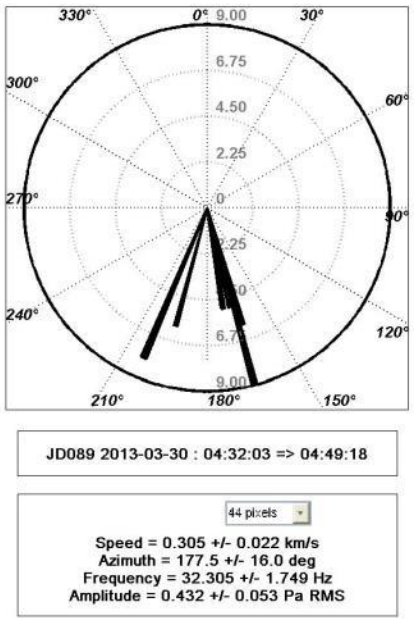
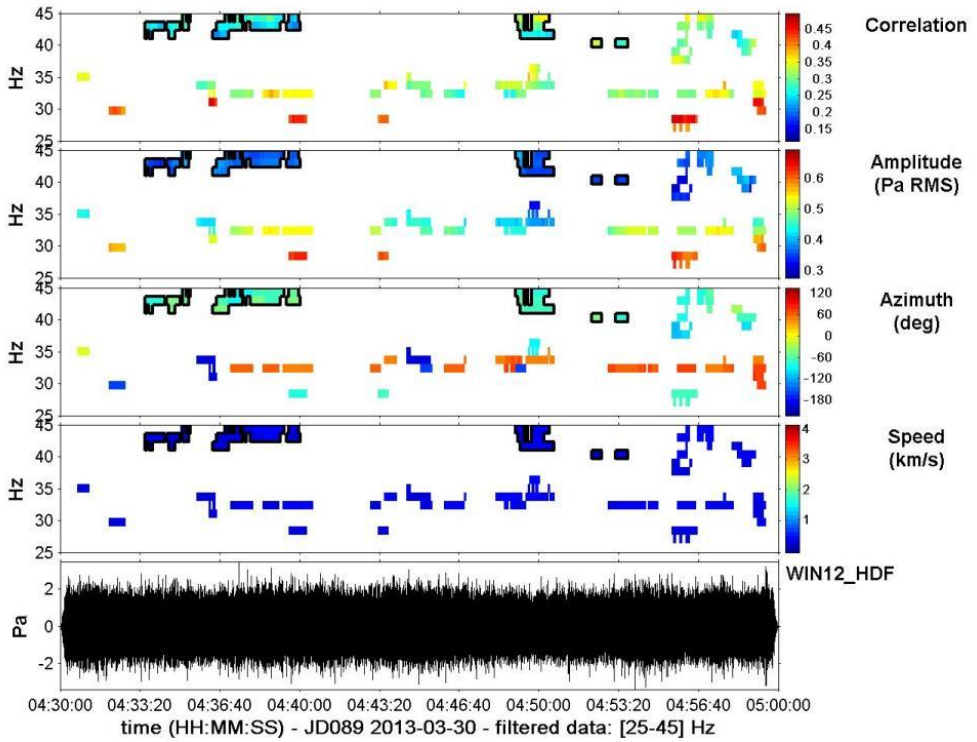

JD089 2013-03-30 : 04:32:03 => 04:49:18
44 pixels
Speed = 0.305 +/- 0.022 km/s
Azimuth = 177.5 +/- 16.0 deg
Frequency = 32.305 +/- 1.749 Hz
Amplitude = 0.432 +/- 0.053 Pa RMS

Figure A2-67


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
04:30:00 04:33:20 04:36:40 04:40:00 04:43:20 04:46:40 04:50:00 04:53:20 04:56:40 05:00:00
time (HH:MM:SS) - JD089 2013-03-30 - filtered data: [25-45] Hz

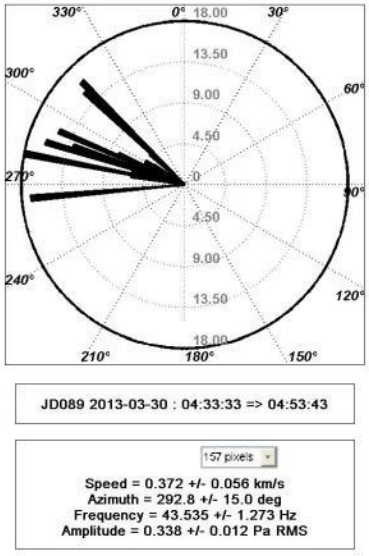
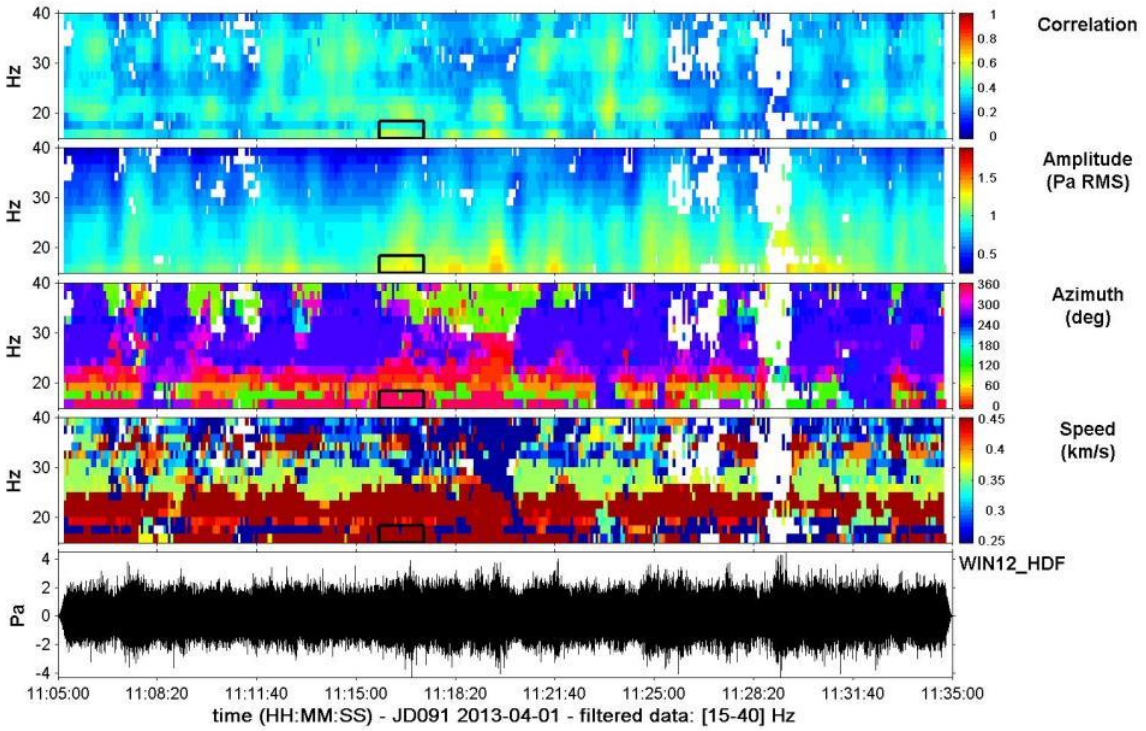
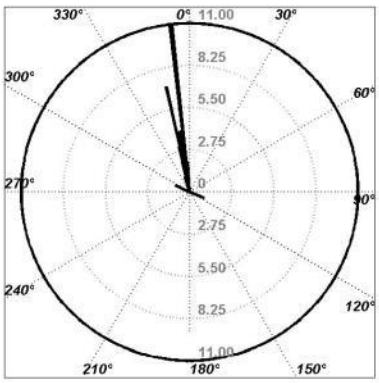

JD089 2013-03-30 : 04:33:33 => 04:53:43
157 pixels
Speed = 0.372 +/- 0.056 km/s
Azimuth = 292.8 +/- 15.0 deg
Frequency = 43.535 +/- 1.273 Hz
Amplitude = 0.338 +/- 0.012 Pa RMS

Figure A2-68



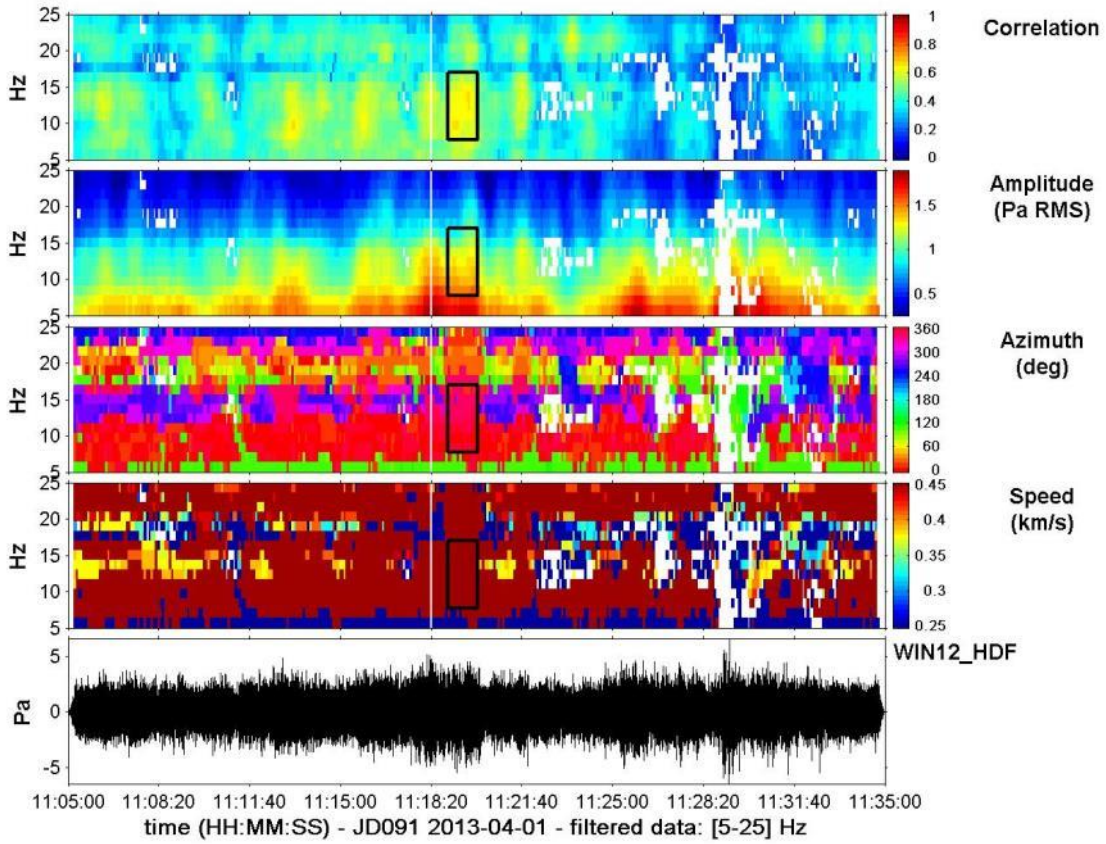


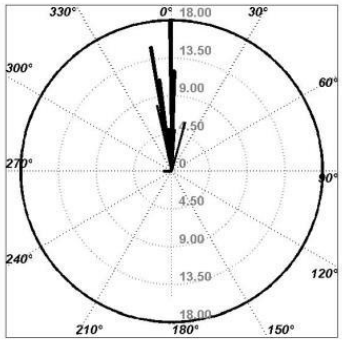
JD091 2013-04-01 : 11:15:47 => 11:17:18

36 pixels

Speed = 0.923 +/- 0.153 km/s
Azimuth = 350.0 +/- 22.8 deg
Frequency = 15.893 +/- 0.906 Hz
Amplitude = 0.854 +/- 0.064 Pa RMS

Figure A2-69



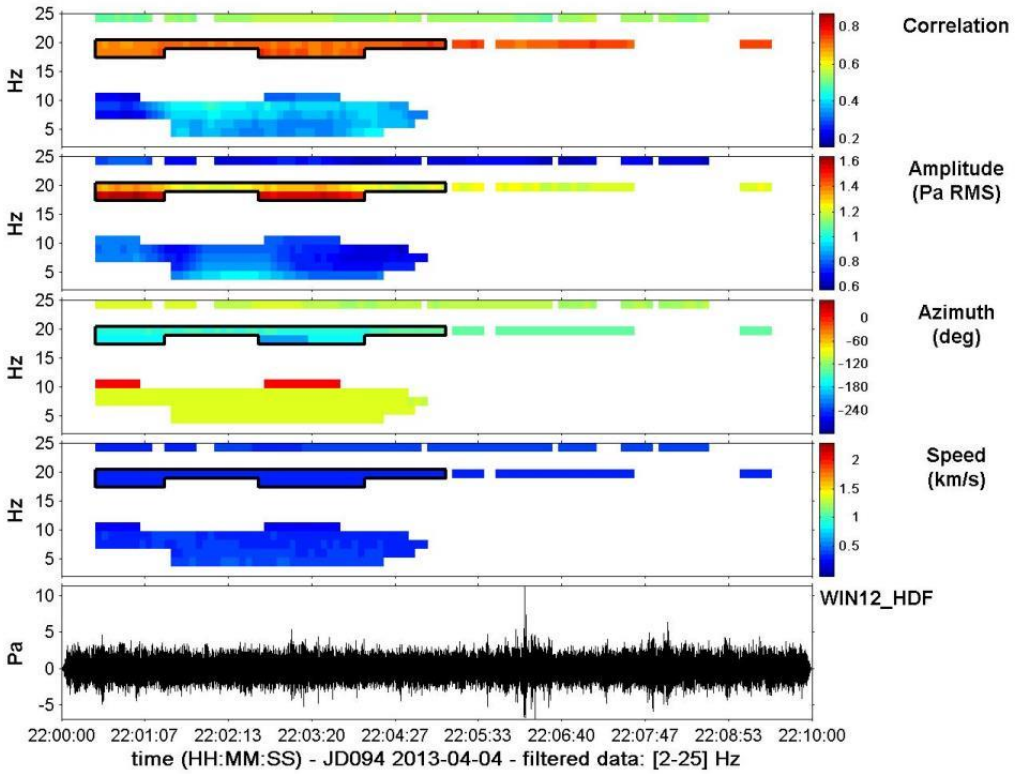


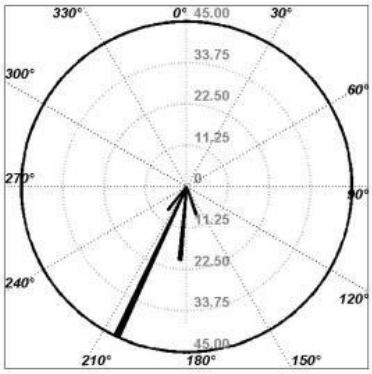
JD091 2013-04-01 : 11:18:58 => 11:20:03

91 pixels

Speed = 0.931 +/- 0.129 km/s
Azimuth = 356.1 +/- 11.4 deg
Frequency = 12.143 +/- 2.873 Hz
Amplitude = 0.939 +/- 0.190 Pa RMS

Figure A2-70



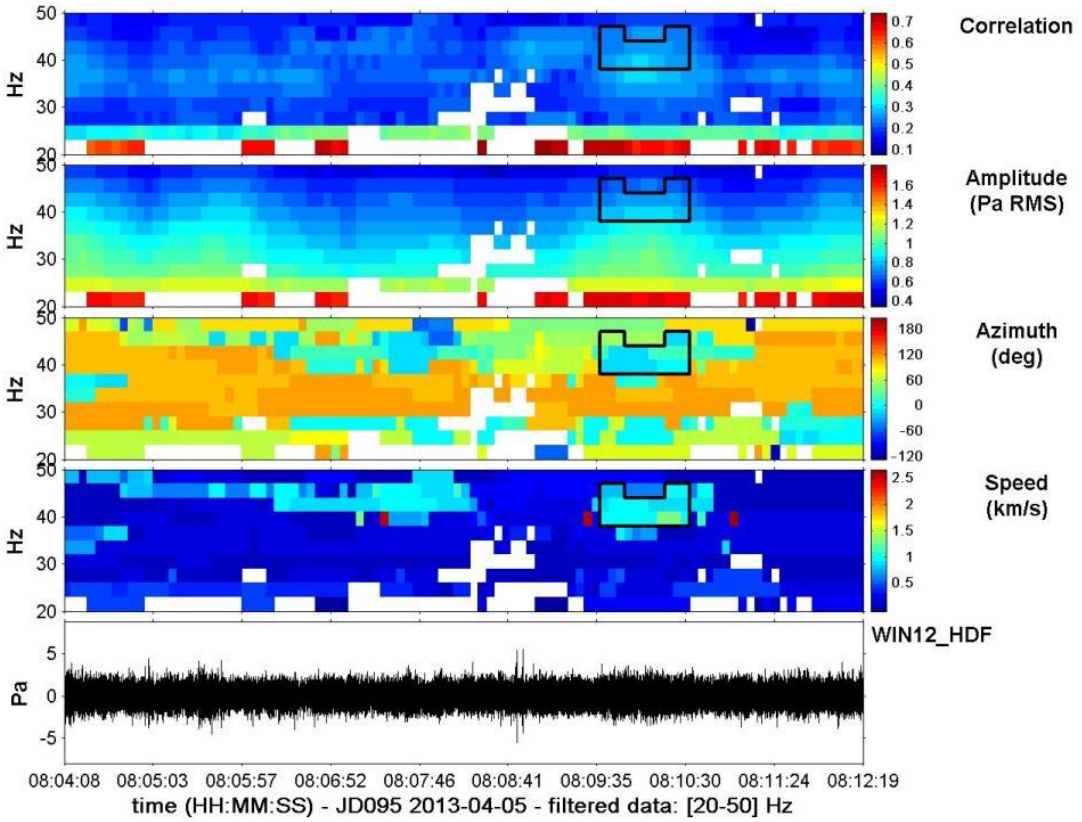


JD094 2013-04-04 : 22:00:28 => 22:05:08

64 pixels

Speed = 0.302 +/- 0.011 km/s
Azimuth = 197.7 +/- 16.0 deg
Frequency = 19.524 +/- 0.779 Hz
Amplitude = 1.281 +/- 0.180 Pa RMS

Figure A2-71


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
08:04:08 08:05:03 08:05:57 08:06:52 08:07:46 08:08:41 08:09:35 08:10:30 08:11:24 08:12:19
time (HH:MM:SS) - JD095 2013-04-05 - filtered data: [20-50] Hz

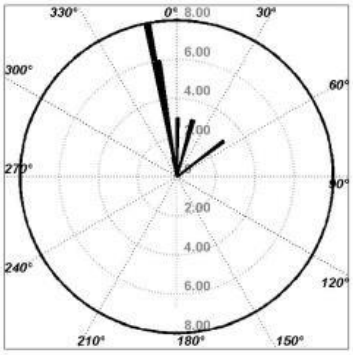
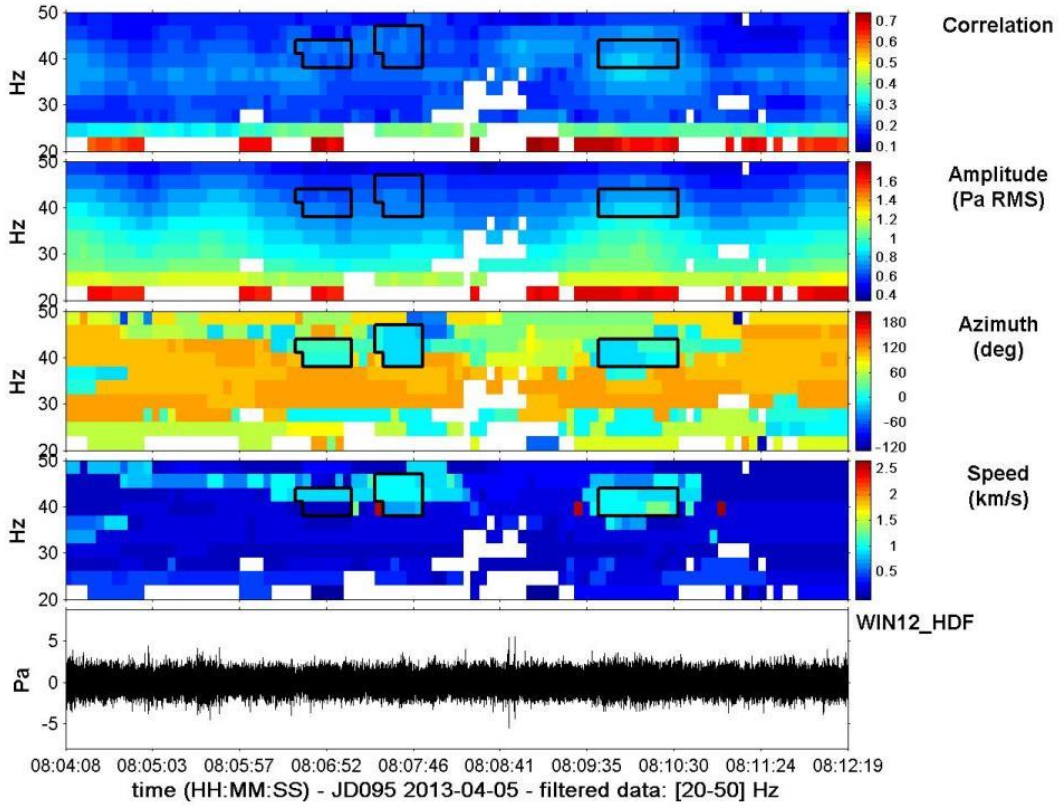

JD095 2013-04-05 : 08:09:38 => 08:10:33
26 pixels
Speed = 0.949 +/- 0.131 km/s
Azimuth = 3.4 +/- 20.4 deg
Frequency = 42.738 +/- 2.575 Hz
Amplitude = 0.566 +/- 0.044 Pa RMS

Figure A2-72


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
08:04:08 08:05:03 08:05:57 08:06:52 08:07:46 08:08:41 08:09:35 08:10:30 08:11:24 08:12:19
time (HH:MM:SS) - JD095 2013-04-05 - filtered data: [20-50] Hz

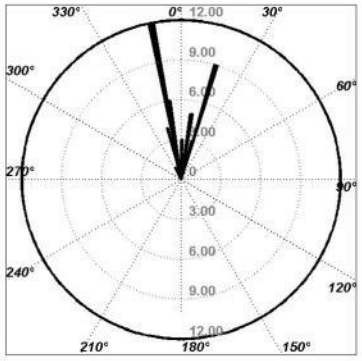
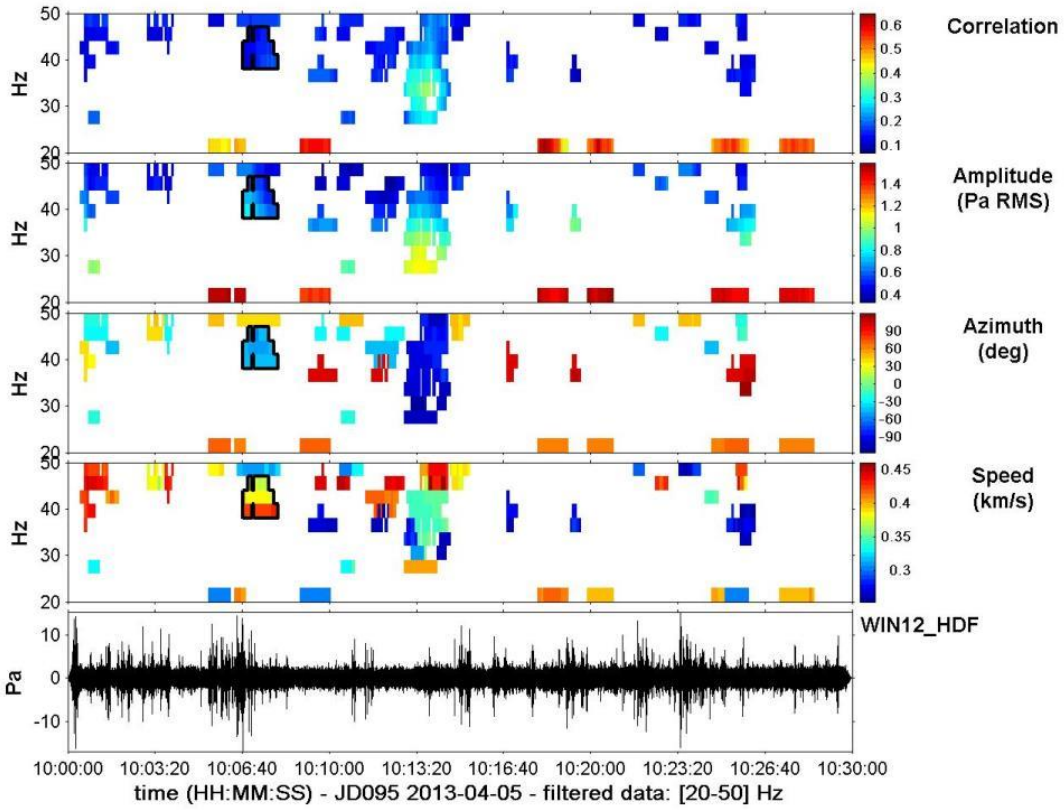
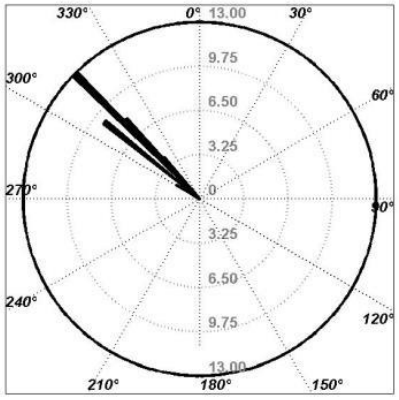

JD095 2013-04-05 : 08:06:33 => 08:10:33
50 pixels
Speed = 0.823 +/- 0.293 km/s
Azimuth = 359.4 +/- 12.6 deg
Frequency = 42.333 +/- 2.259 Hz
Amplitude = 0.542 +/- 0.044 Pa RMS

Figure A2-73





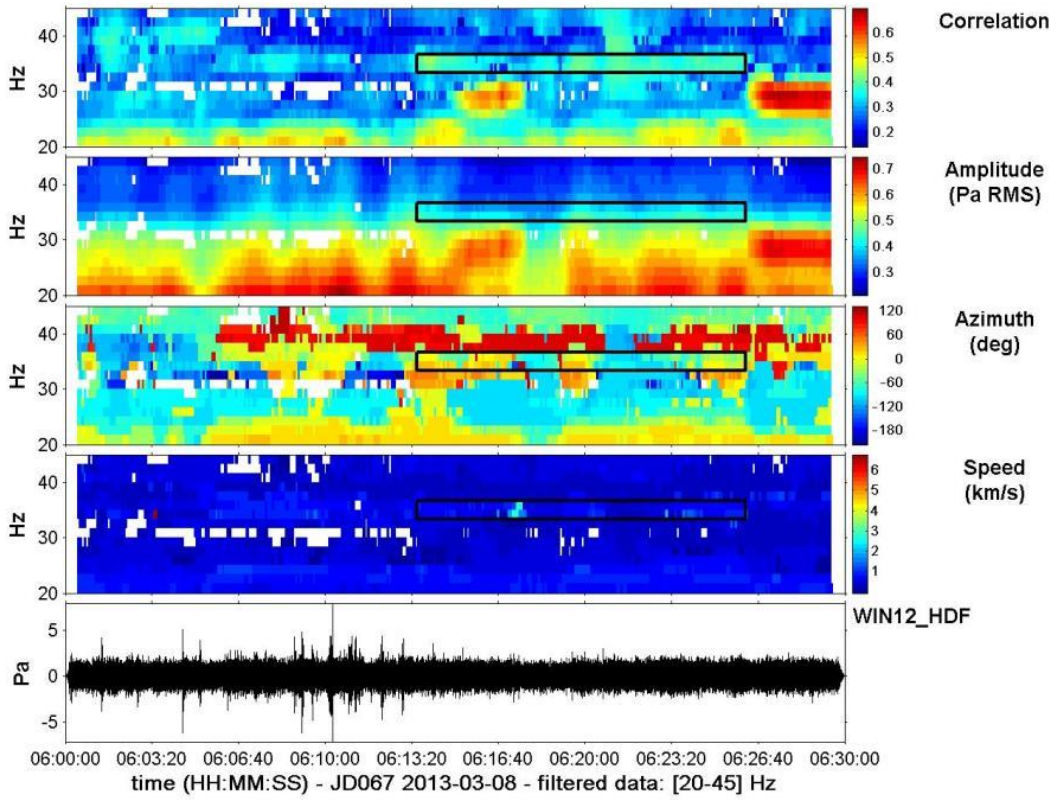
JD095 2013-04-05 : 10:06:42 => 10:08:02

30 pixels

Speed = 0.398 +/- 0.025 km/s
Azimuth = 313.9 +/- 4.5 deg
Frequency = 42.807 +/- 2.631 Hz
Amplitude = 0.502 +/- 0.054 Pa RMS

Figure A2-74

Appendix 2c: Array 1 – Examples of signals at Array 1 (Windsor Salt) for select dates and time segments depicting uncertainties in direction and examples of the frequency spectrum at times when public reports indicate Hum activity.



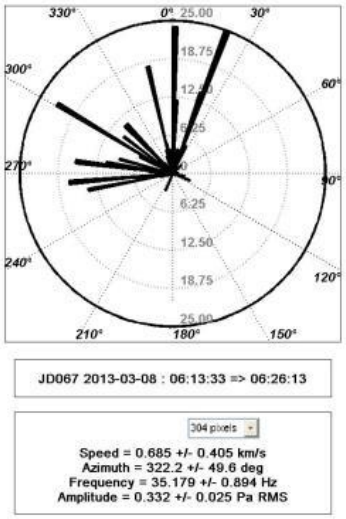


Figure A2-75

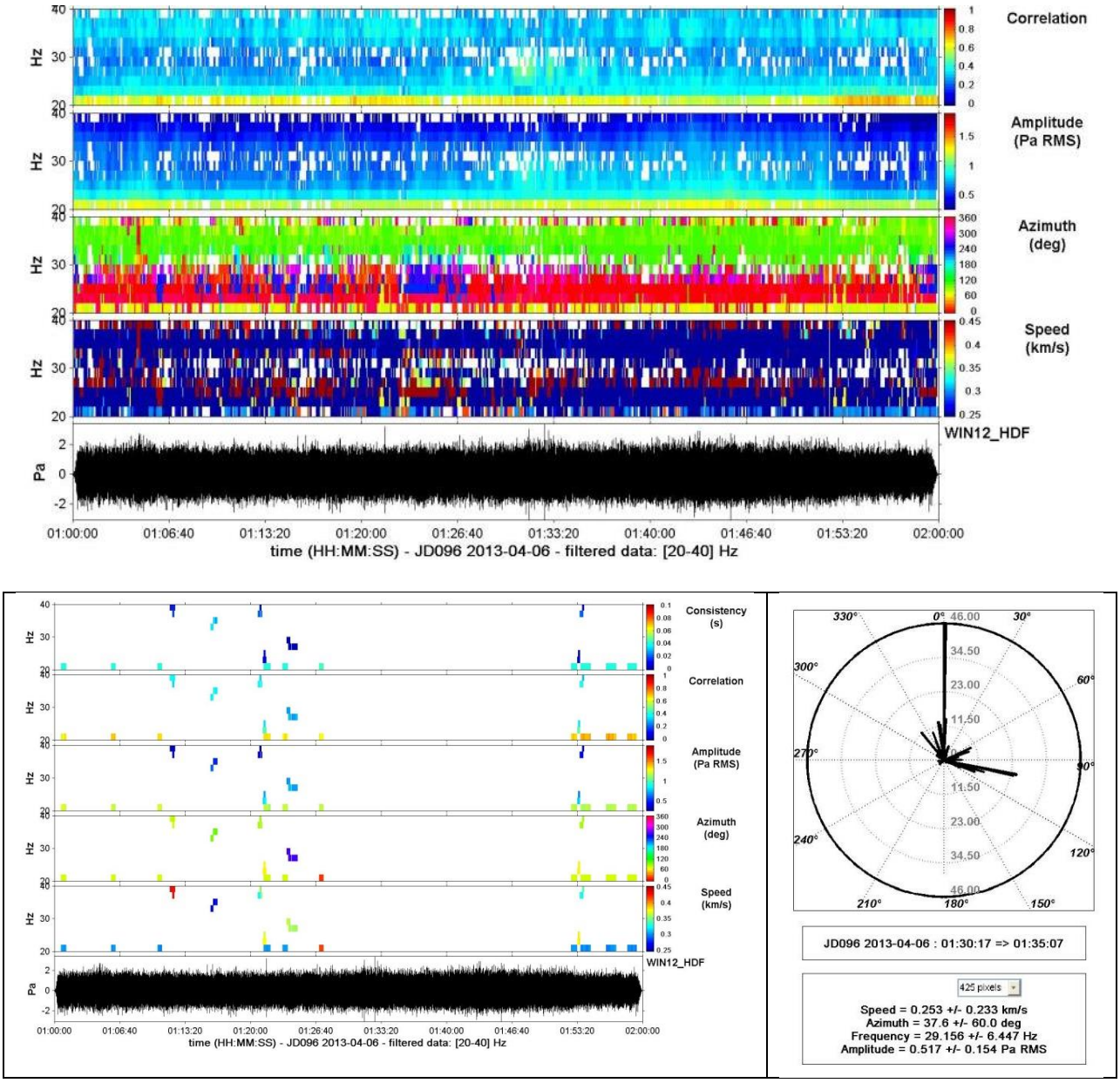
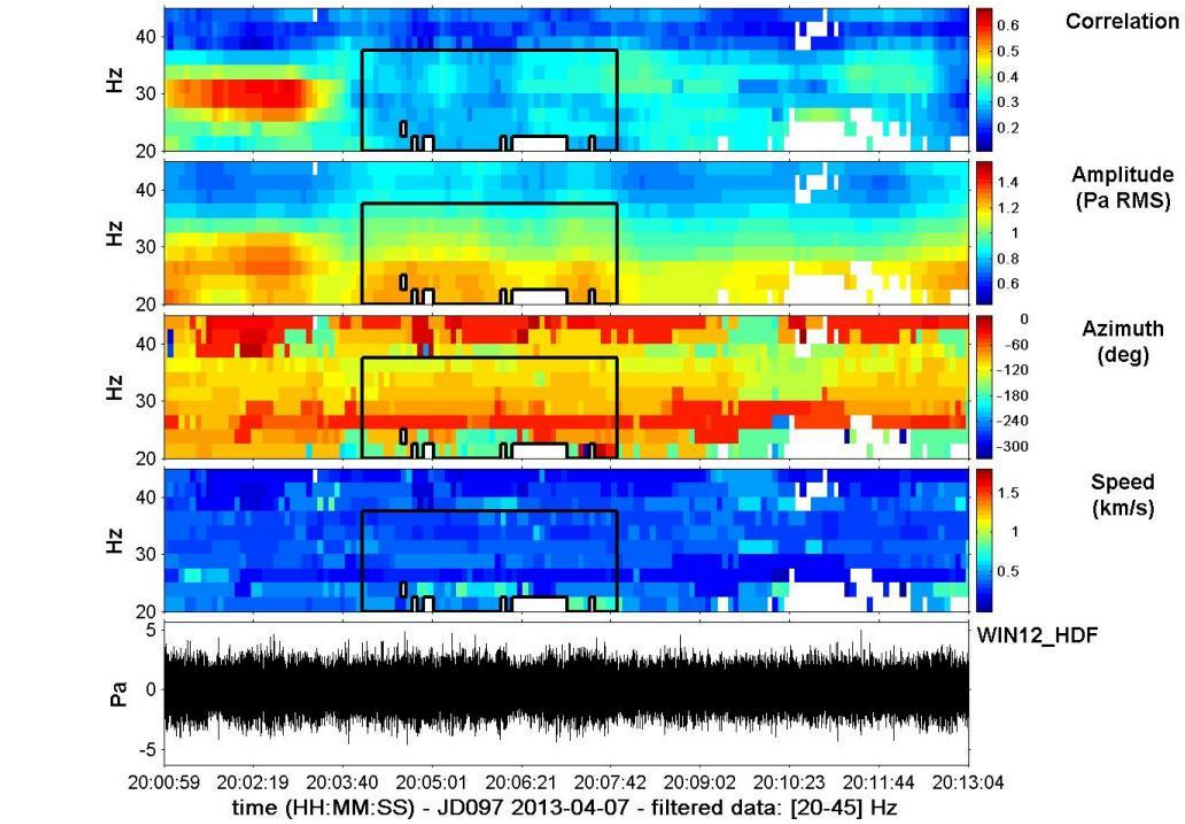

Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
01:00:00
01:06:40
01:13:20
01:20:00
01:26:40
01:33:20
01:40:00
01:46:40
01:53:20
02:00:00
time (HH:MM:SS) - JD096 2013-04-06 - filtered data: [20-40] Hz
Consistency (s)
330°
0°
30°
300°
60°
270°
90°
240°
120°
210°
180°
150°
46.00
34.50
23.00
11.50
JD096 2013-04-06 : 01:30:17 => 01:35:07
425 pixels
Speed = 0.253 +/- 0.233 km/s
Azimuth = 37.6 +/- 60.0 deg
Frequency = 29.156 +/- 6.447 Hz
Amplitude = 0.517 +/- 0.154 Pa RMS

Figure A2-76


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
20:00:59 20:02:19 20:03:40 20:05:01 20:06:21 20:07:42 20:09:02 20:10:23 20:11:44 20:13:04
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [20-45] Hz

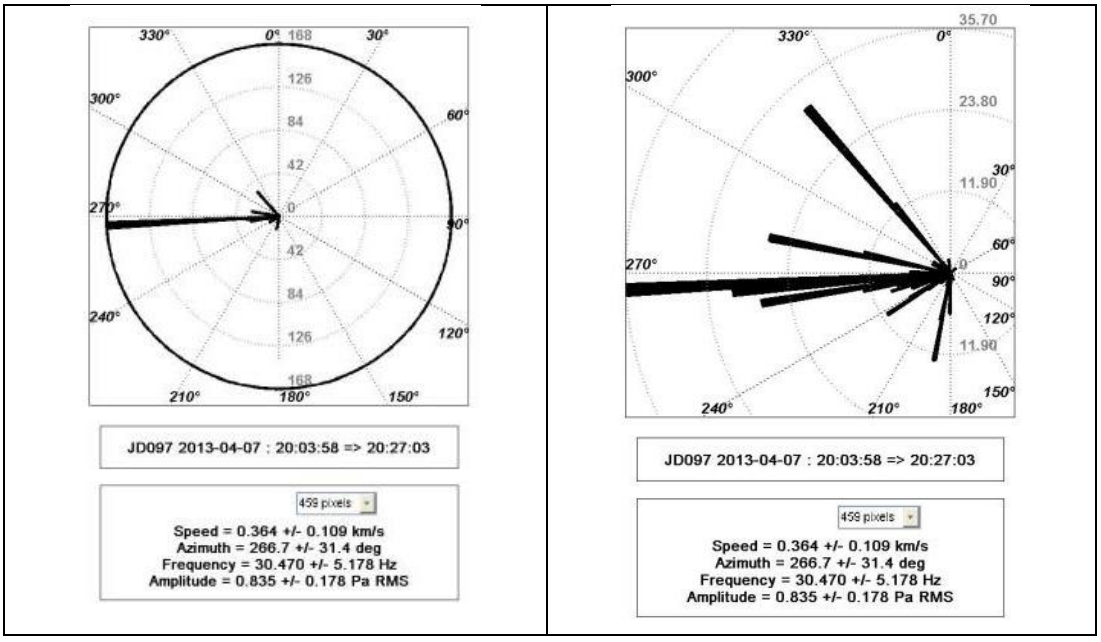

JD097 2013-04-07 : 20:03:58 => 20:27:03
459 pixels
Speed = 0.364 +/- 0.109 km/s
Azimuth = 266.7 +/- 31.4 deg
Frequency = 30.470 +/- 5.178 Hz
Amplitude = 0.835 +/- 0.178 Pa RMS
JD097 2013-04-07 : 20:03:58 => 20:27:03
459 pixels
Speed = 0.364 +/- 0.109 km/s
Azimuth = 266.7 +/- 31.4 deg
Frequency = 30.470 +/- 5.178 Hz
Amplitude = 0.835 +/- 0.178 Pa RMS

Figure A2-77

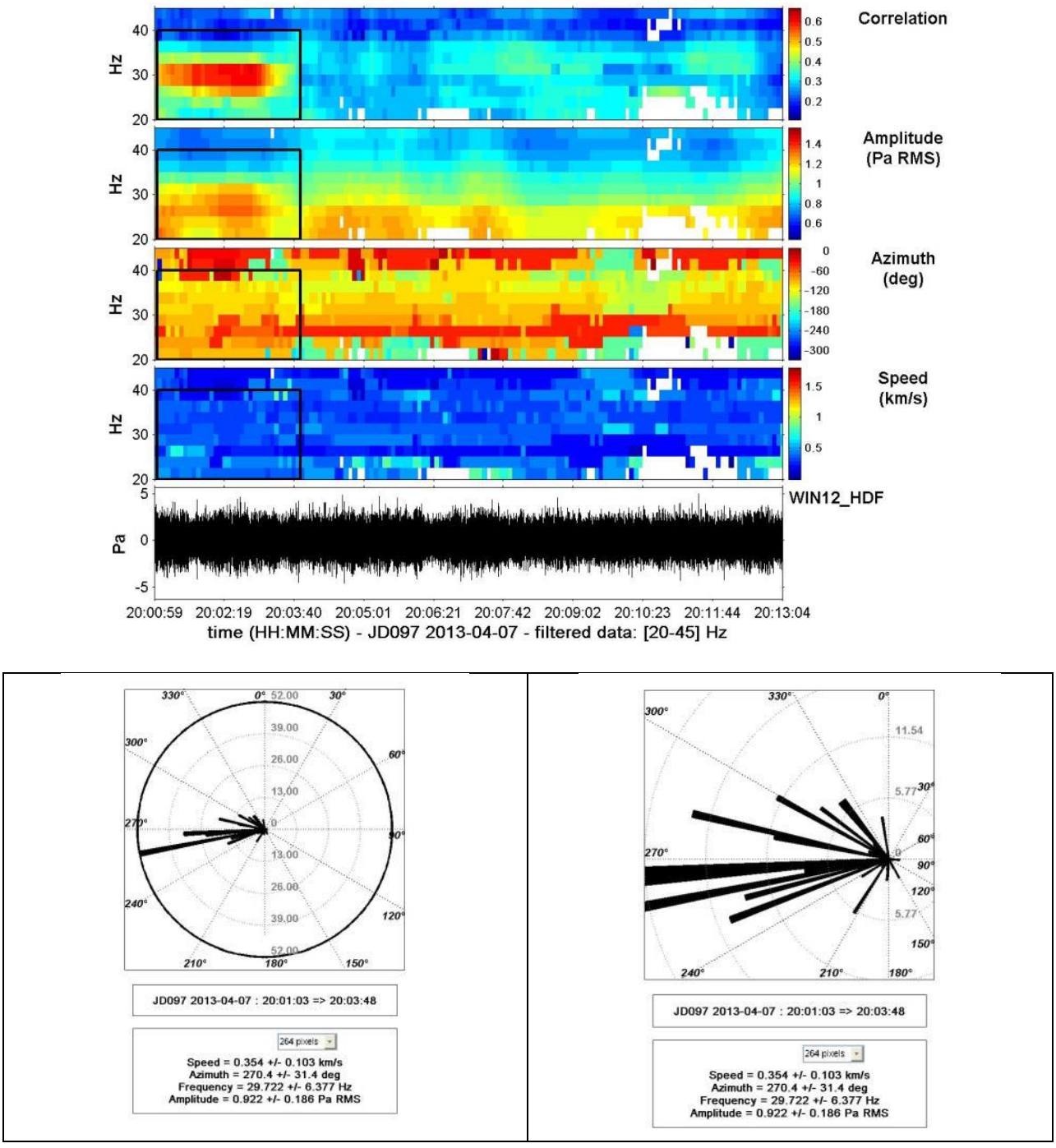
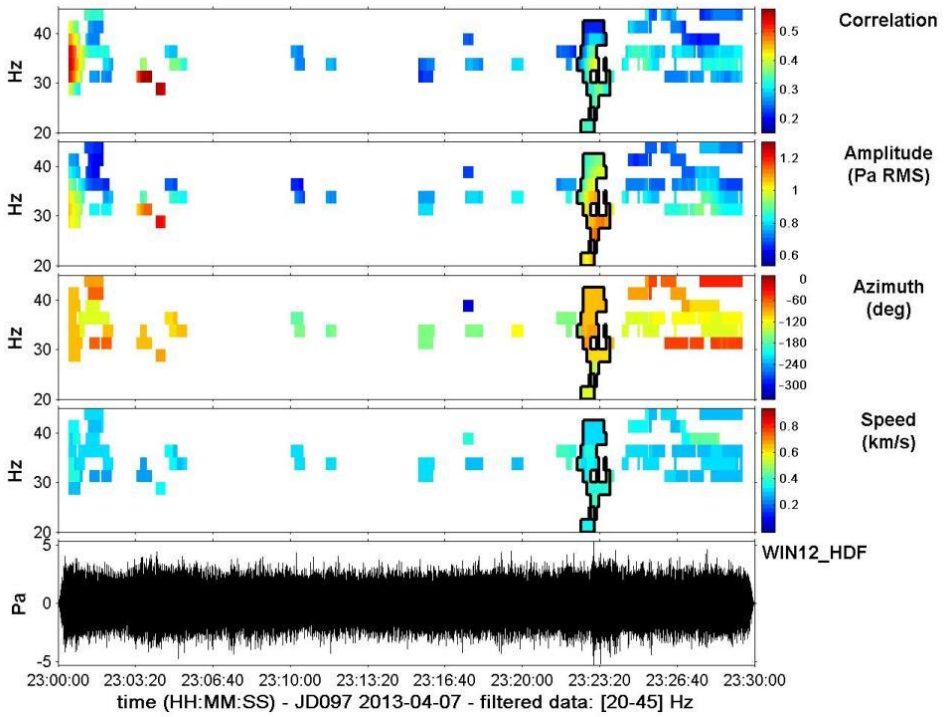

Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
20:00:59 20:02:19 20:03:40 20:05:01 20:06:21 20:07:42 20:09:02 20:10:23 20:11:44 20:13:04
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [20-45] Hz
JD097 2013-04-07 : 20:01:03 => 20:03:48
264 pixels
Speed = 0.354 +/- 0.103 km/s
Azimuth = 270.4 +/- 31.4 deg
Frequency = 29.722 +/- 6.377 Hz
Amplitude = 0.922 +/- 0.186 Pa RMS
JD097 2013-04-07 : 20:01:03 => 20:03:48
264 pixels
Speed = 0.354 +/- 0.103 km/s
Azimuth = 270.4 +/- 31.4 deg
Frequency = 29.722 +/- 6.377 Hz
Amplitude = 0.922 +/- 0.186 Pa RMS

Figure A2-78


Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN12_HDF
Hz
Pa
23:00:00 23:03:20 23:06:40 23:10:00 23:13:20 23:16:40 23:20:00 23:23:20 23:26:40 23:30:00
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [20-45] Hz

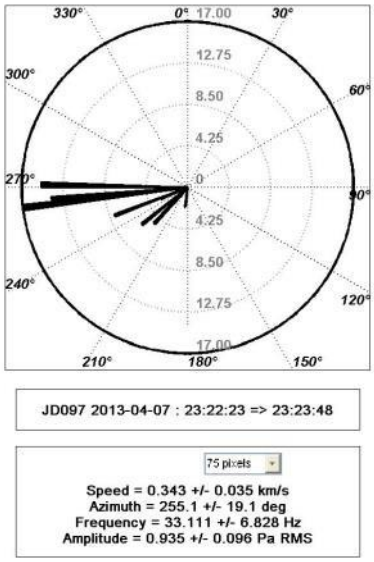

0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
17.00
12.75
8.50
4.25
0
4.25
8.50
12.75
17.00
JD097 2013-04-07 : 23:22:23 => 23:23:48
75 pixels
Speed = 0.343 +/- 0.035 km/s
Azimuth = 255.1 +/- 19.1 deg
Frequency = 33.111 +/- 6.828 Hz
Amplitude = 0.935 +/- 0.096 Pa RMS

Figure A2-79

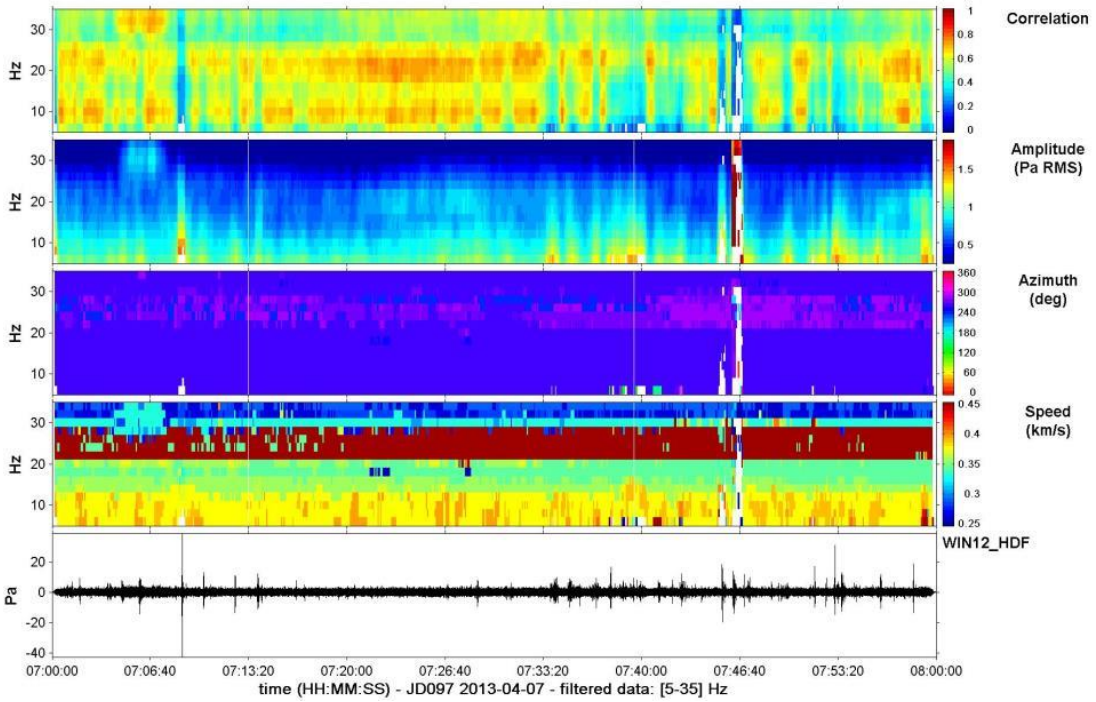


Figure A2-80

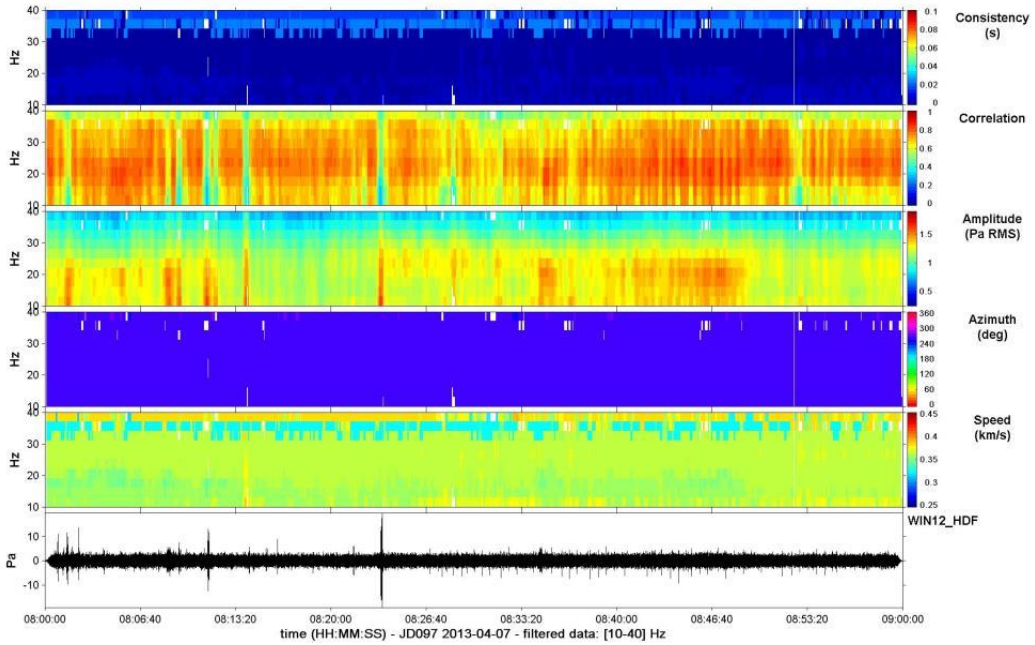


Figure A2-81

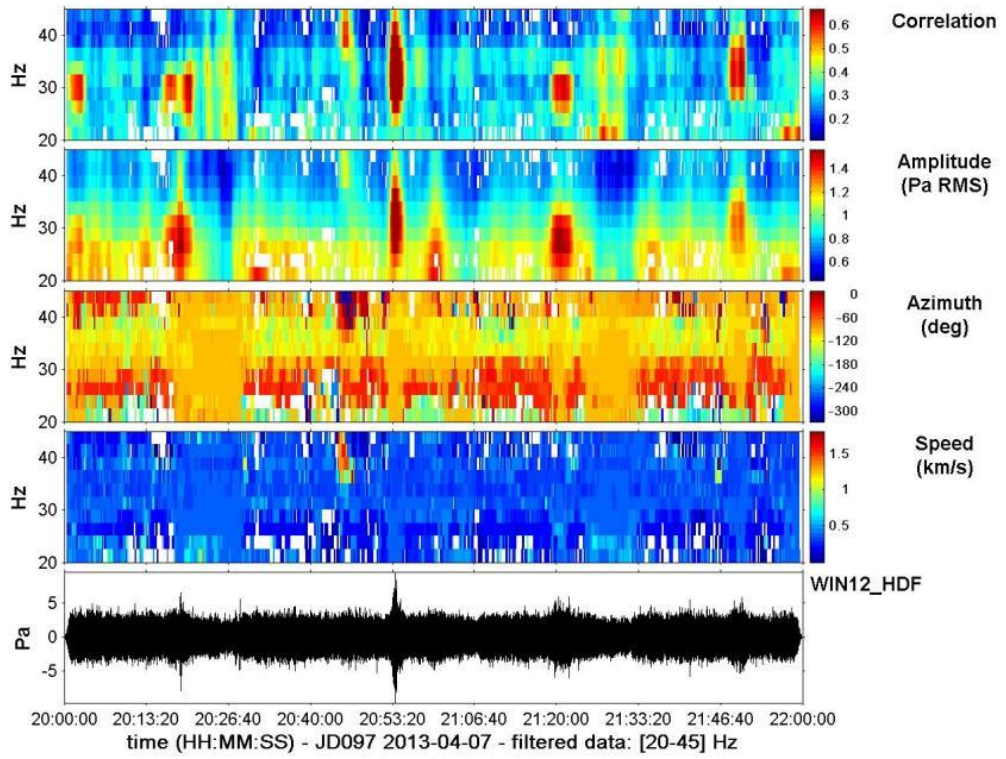

Correlation
Amplitude
(Pa RMS)
Azimuth
(deg)
Speed
(km/s)
WIN12_HDF
Hz
Pa
20:00:00 20:13:20 20:26:40 20:40:00 20:53:20 21:06:40 21:20:00 21:33:20 21:46:40 22:00:00
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [20-45] Hz

Figure A2-82

Appendix 2d: Array 2 (Transport Canada) - Examples of the PMCC results for select dates and time segments when public reports indicate some Hum activity.

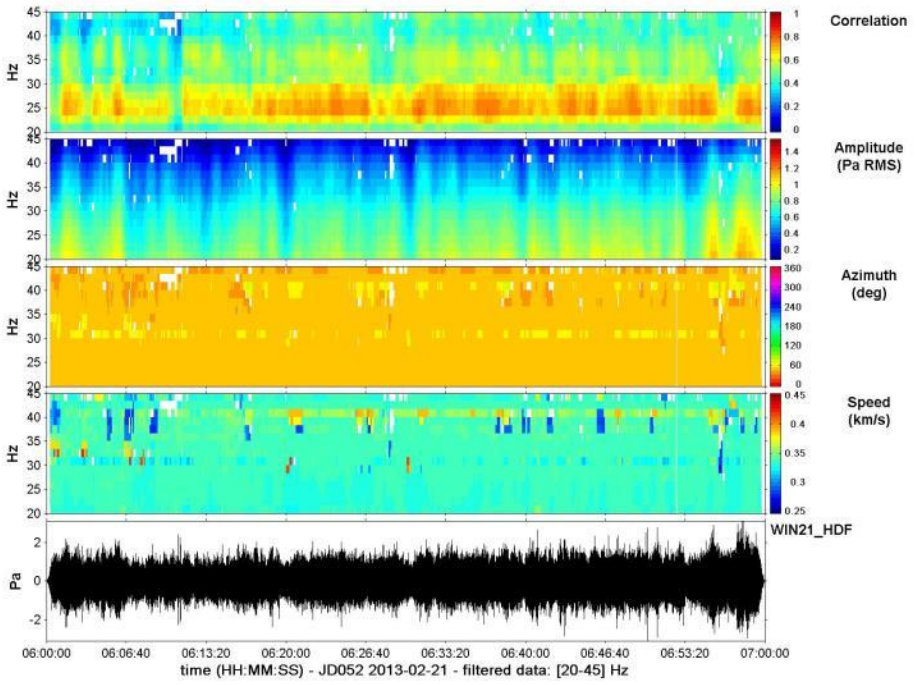


Figure A2-83

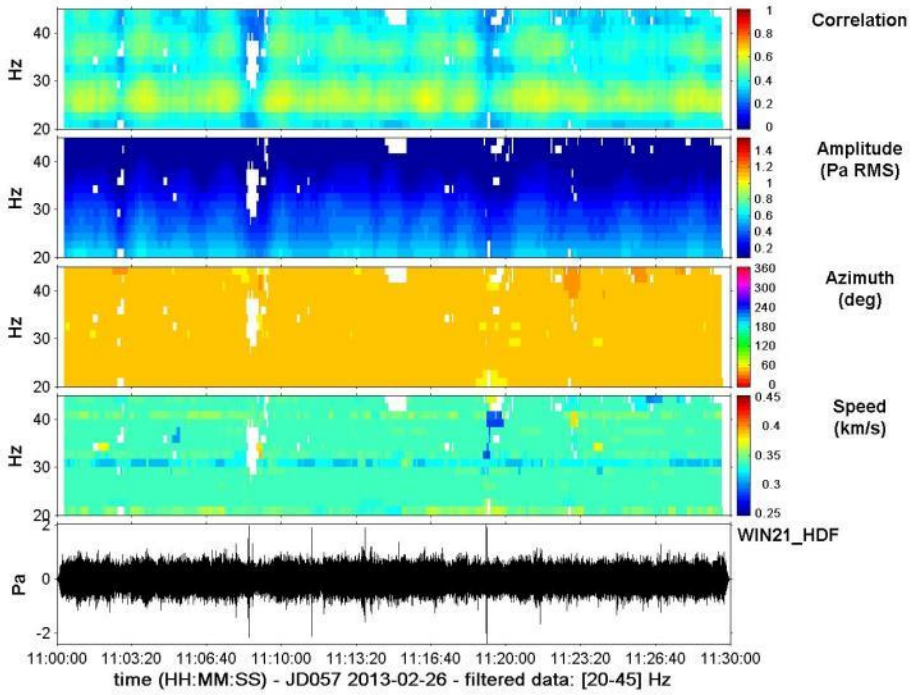


Figure A2-84

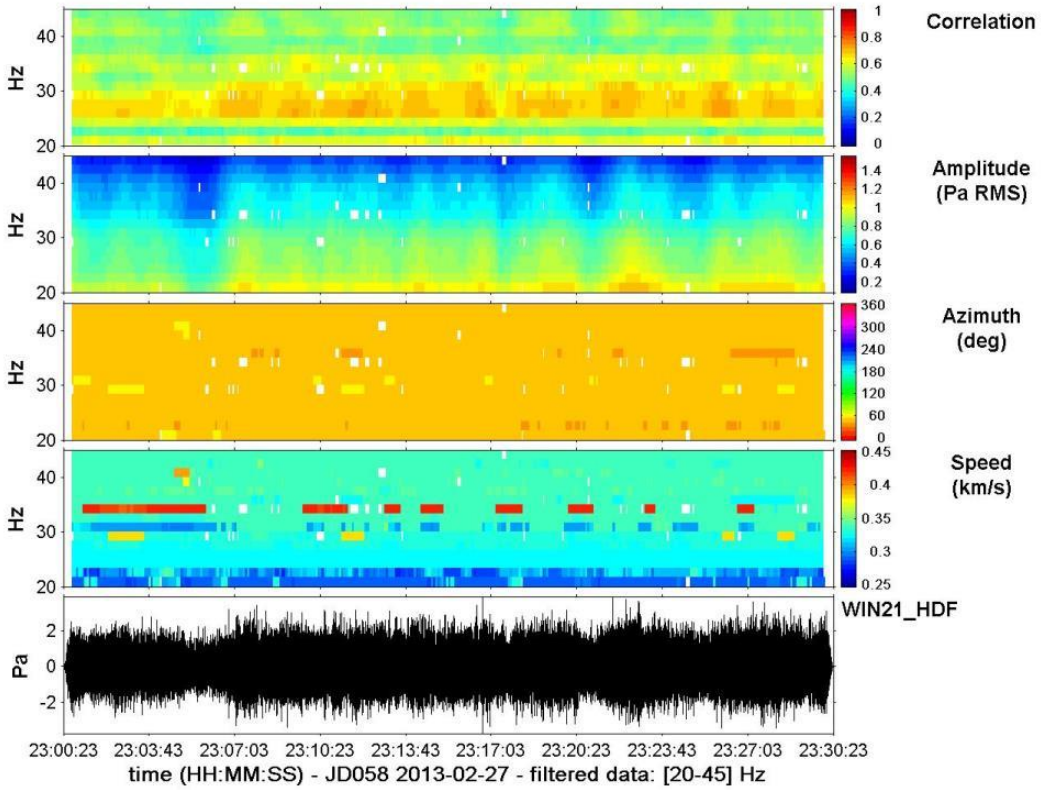


Figure A2-85

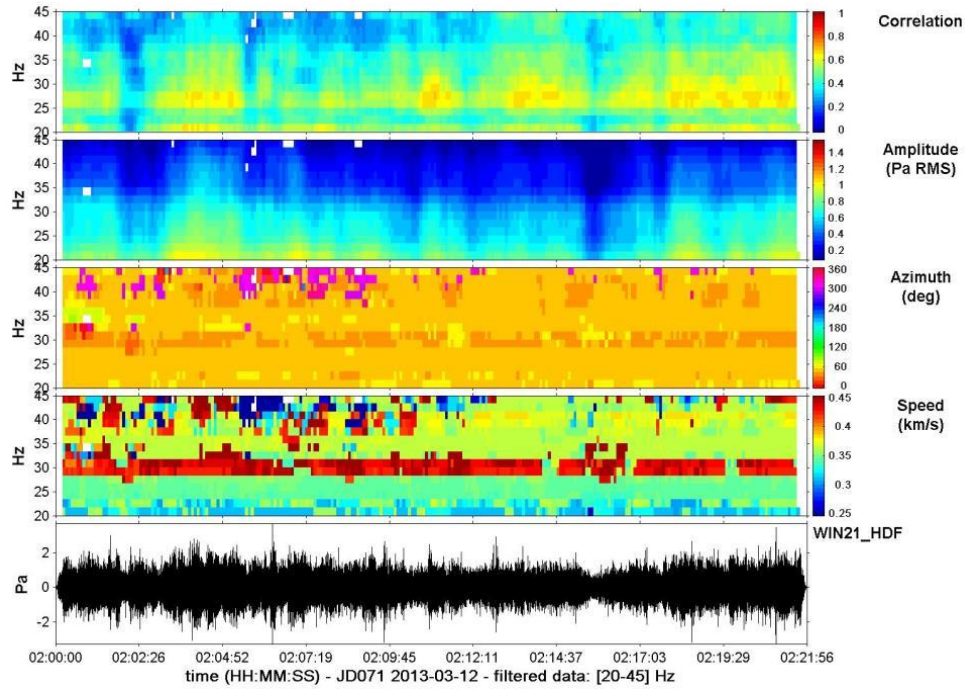


Figure A2-86

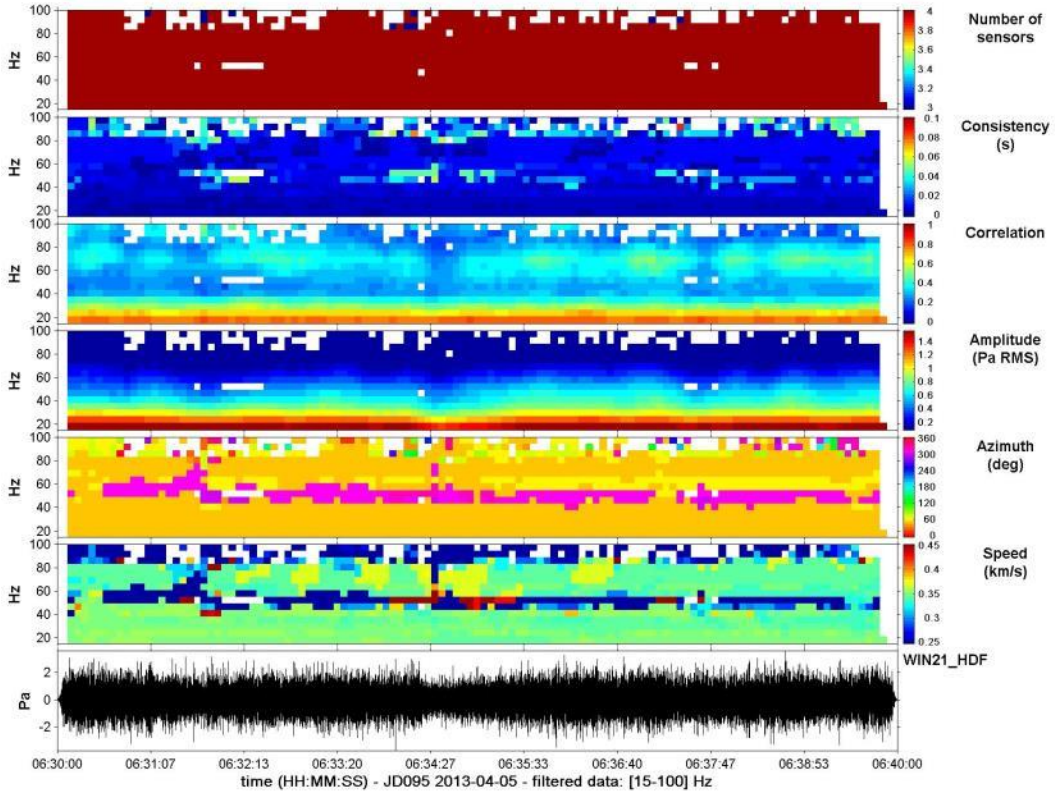


Figure A2-87

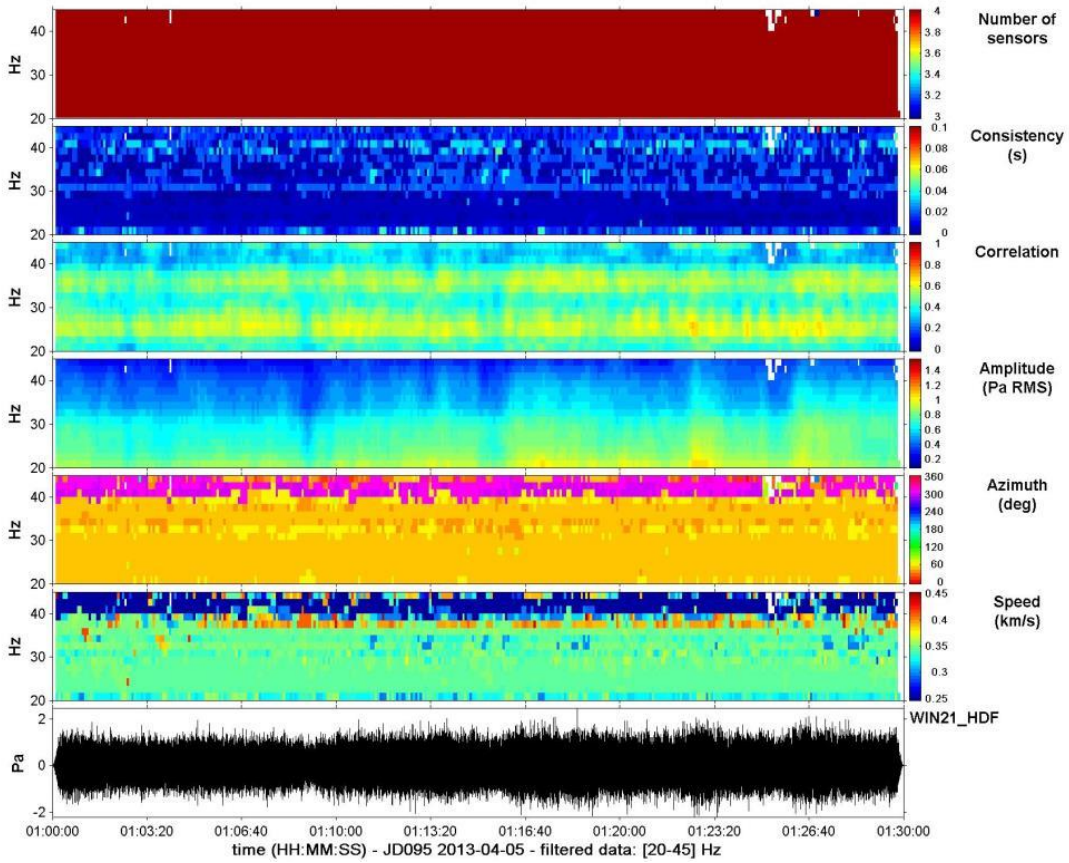

Number of sensors
Consistency (s)
Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN21_HDF
Hz
Pa
01:00:00
01:03:20
01:06:40
01:10:00
01:13:20
01:16:40
01:20:00
01:23:20
01:26:40
01:30:00
time (HH:MM:SS) - JD095 2013-04-05 - filtered data: [20-45] Hz

Figure A2-88

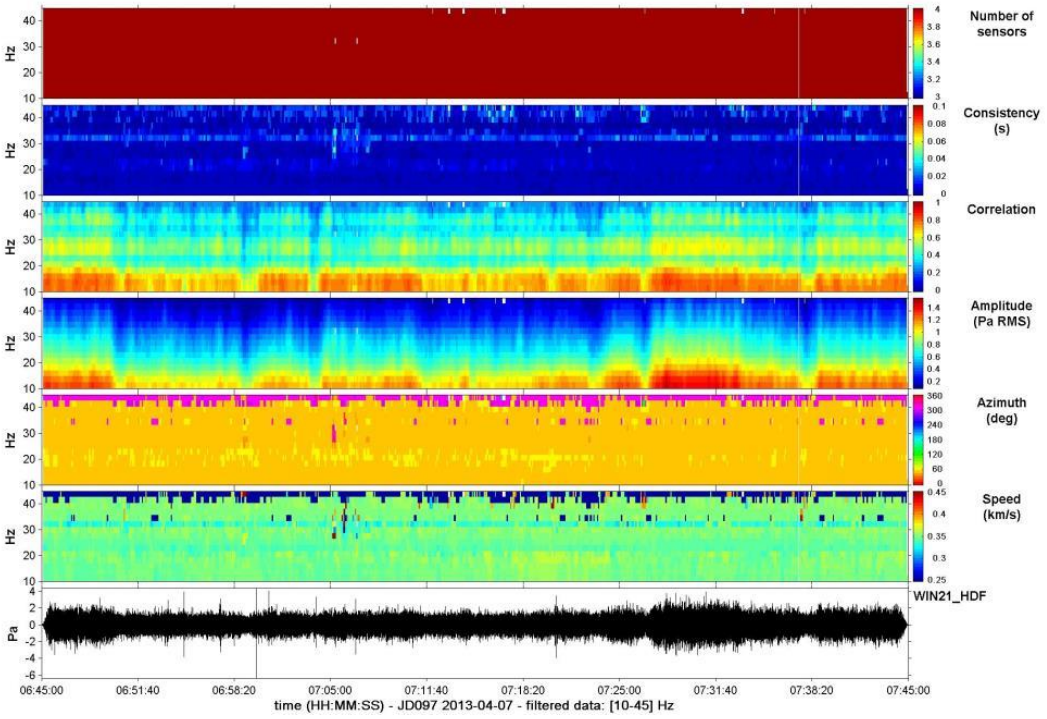

Number of sensors
Consistency (s)
Correlation
Amplitude (Pa RMS)
Azimuth (deg)
Speed (km/s)
WIN21_HDF
Hz
Pa
06:45:00
06:51:40
06:58:20
07:05:00
07:11:40
07:18:20
07:25:00
07:31:40
07:38:20
07:45:00
time (HH:MM:SS) - JD097 2013-04-07 - filtered data: [10-45] Hz

Figure A2-89