A long day full of whistlers

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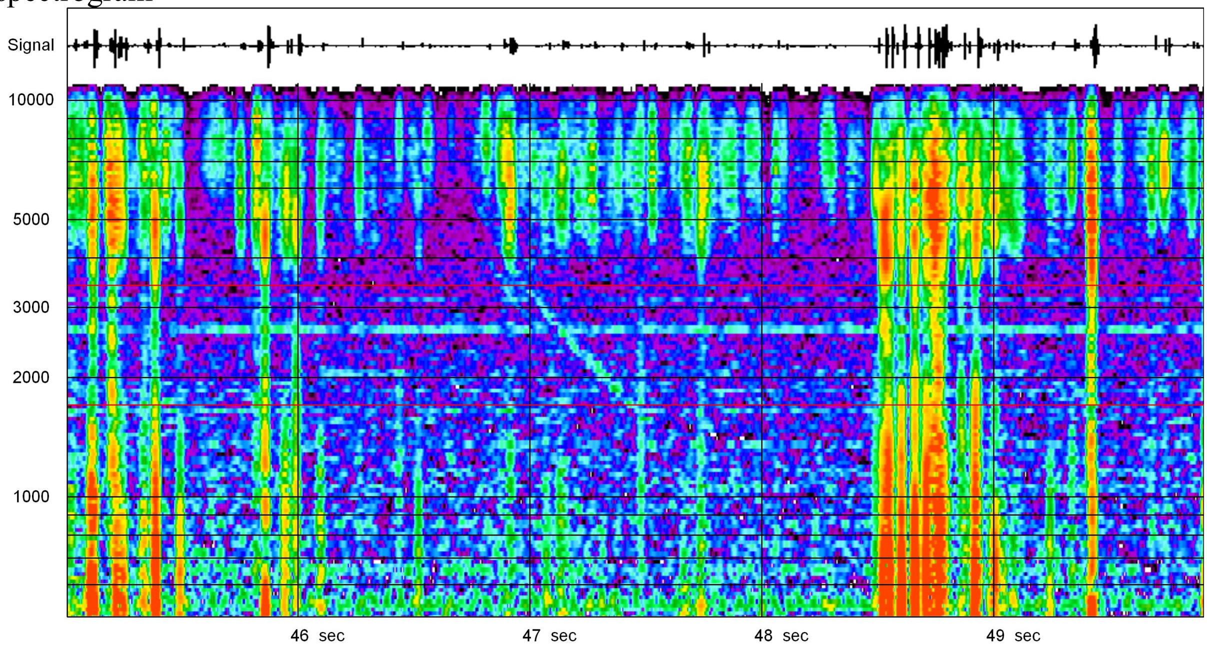
When I am at my home in Kiel, on the coast of the Baltic Sea, I go as often as possible for a long walk along the beach. In my back pack there is the lunch, a book, and my VLF receiver. Of course, there also is a tape recorder and spare batteries! Although I've done that walk many times, I haven't got tired of it, each day is different, the colours are different, the sky, the clouds, the sea … and what I can hear on VLF. This summer, august 18th proved to be a long one!

My equipment: VLF receiver, whip antenna, earphones, cassette tape recorder, audio cable

On my path along the coastline, I have found a couple of stations where the hum from the mains power – from houses and street lamps – is very low or absent. Leaving the bus that brought me to a seaside village, I went straight to my first station, a sandy peninsula far from the houses, there took out the receiver and started to listen for about a minute (you might say: as usual). As I heard almost immediately a swishing sound among the medium strong spherics, I got out the tape recorder and started it. A typical whistler is shown in the following spectrogram



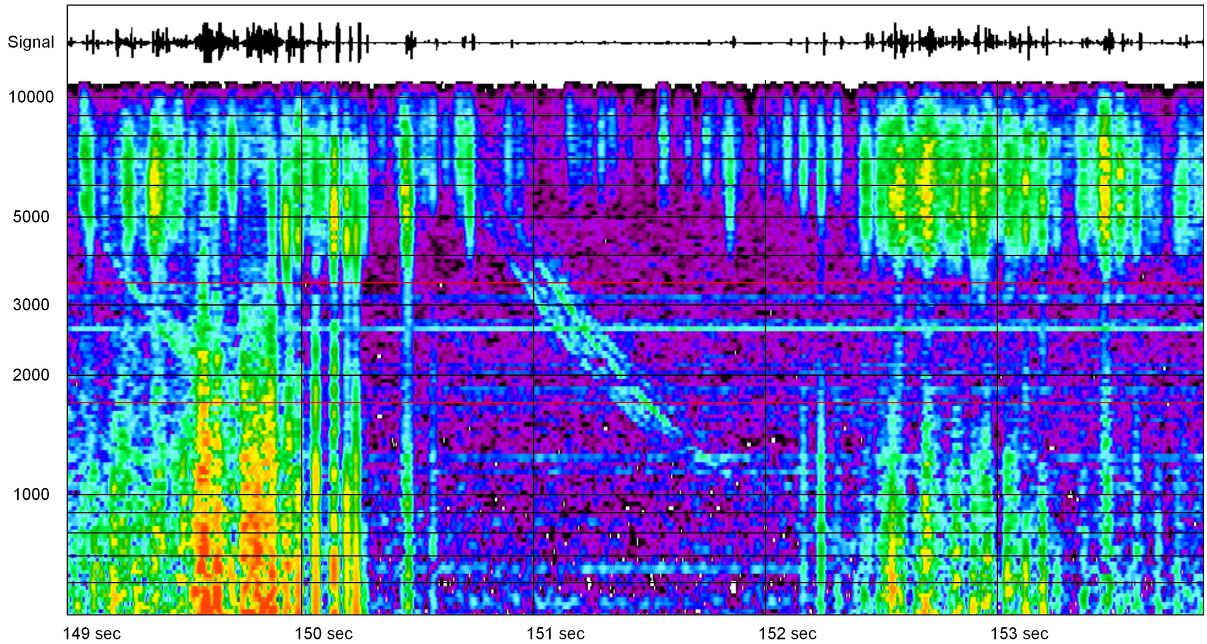
Spectrogram of a whistler at about 47 sec after 12:42 CEST, done with Gram 16.0. The two red horizontal lines mark frequencies of 1700 and 3400 Hz.

The frequency axis I chose to be logarithmic, because whistlers would show up as nearly straight lines, whose slope one can more easily measure than with a linear frequency scale. This one starts at 6000 Hz and sweeps down to about 1600 Hz.; it takes 0.4 seconds to drop from 4000 to 2000 Hz. Based on previous experience, this tells me that the whistler is a one-hop variety, coming from south Africa. There also is another, much shorter whistler, showing up only near 3000 Hz. As I do not carry with me any equipment to put accurate time ticks on the recorder, the times I give here are the seconds after the start of the recording, whose time I simply noted from my wrist watch, but only as the nearest full minute.

At this time and place, I observed about 6 whistlers per minute. This number was obtained later, by listing to the audio file and simply counting all whistling sounds. The whistler shown above was nearly pure-tone, but I also heard several more hissy ones, which are composed of several whistlers spaced very closely in time, between 0.1 to 0.4 sec. In my count, I do not (yet) distinguish between faint and strong ones, or pure-tone and multiple whistlers. Let us first get a rough idea, and let us see how the whistler frequency evolves during this day!

Often I had noticed before that I might not hear any whistlers half an hour later. So on this day I kept listening and recording, about every half hour – the background hum permitting. All recordings were done with the same receiver, the tape recordings converted into audio files using the same play back volume, and I shall show the results using always the same time span and the same parameter settings of the Gram software.

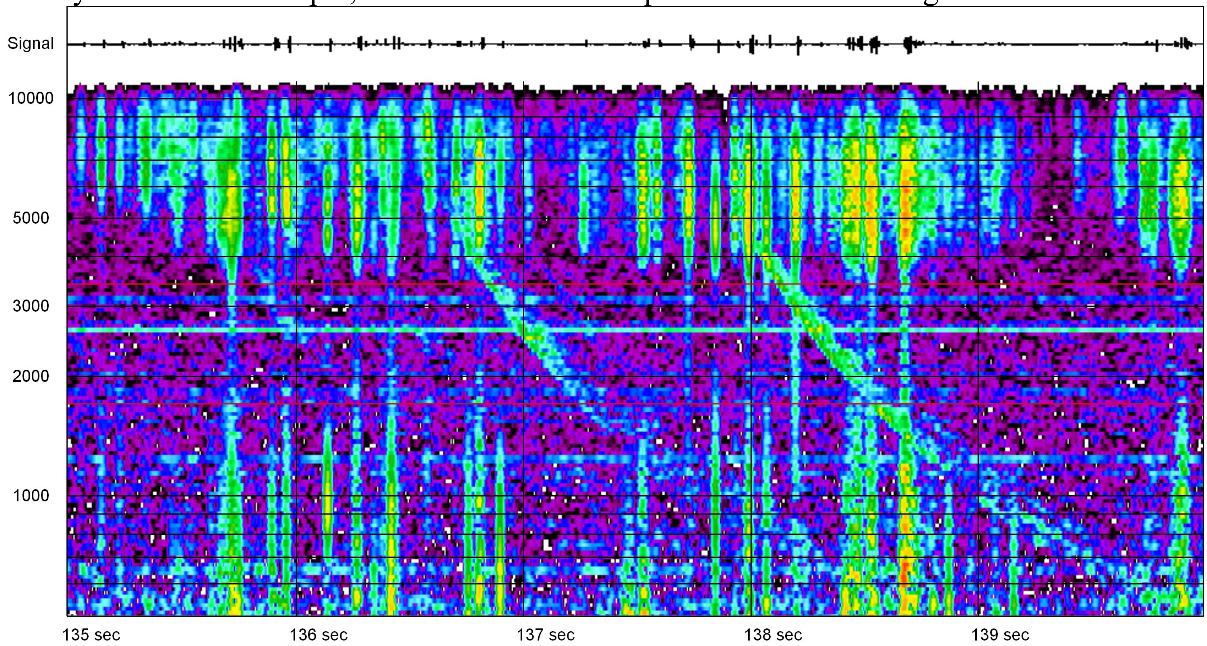
My next station unfortunately is within sight of an overland power line, thus the hum background is stronger which prevents to hear the fainter whistlers. However, I was gratified by numerous whistlers which also appeared to be louder. One example of a multiple one is shown below:



A multiple-component whistler at 151 sec after 13:35 CEST

One may distinguish 5 or 6 components, separated by as little as 0.05 sec; they start at about 6000 Hz and reach frequencies as low as 1200 Hz. This is already quite noticeable during the direct listening, by the lower frequency and also by the longer duration of the entire feature.

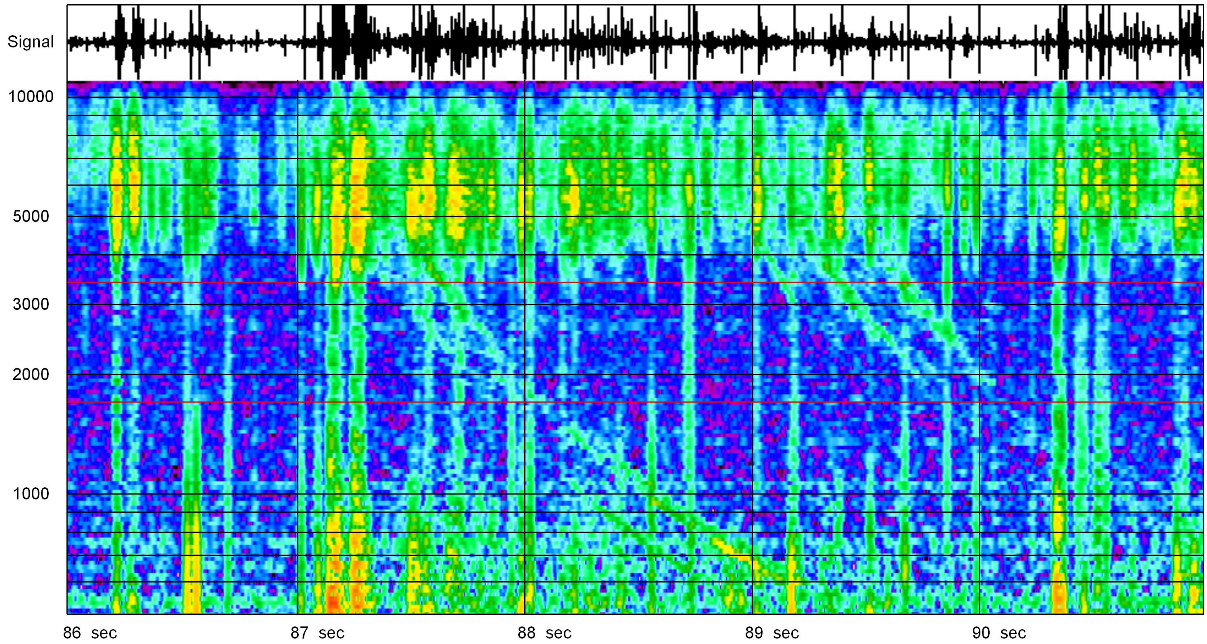
Shortly before this example, there came an almost pure-tone one reaching down to 1000 Hz:



A long-drawn whistler at 138 sec after 13:35 CEST reaching down to 1000 Hz.

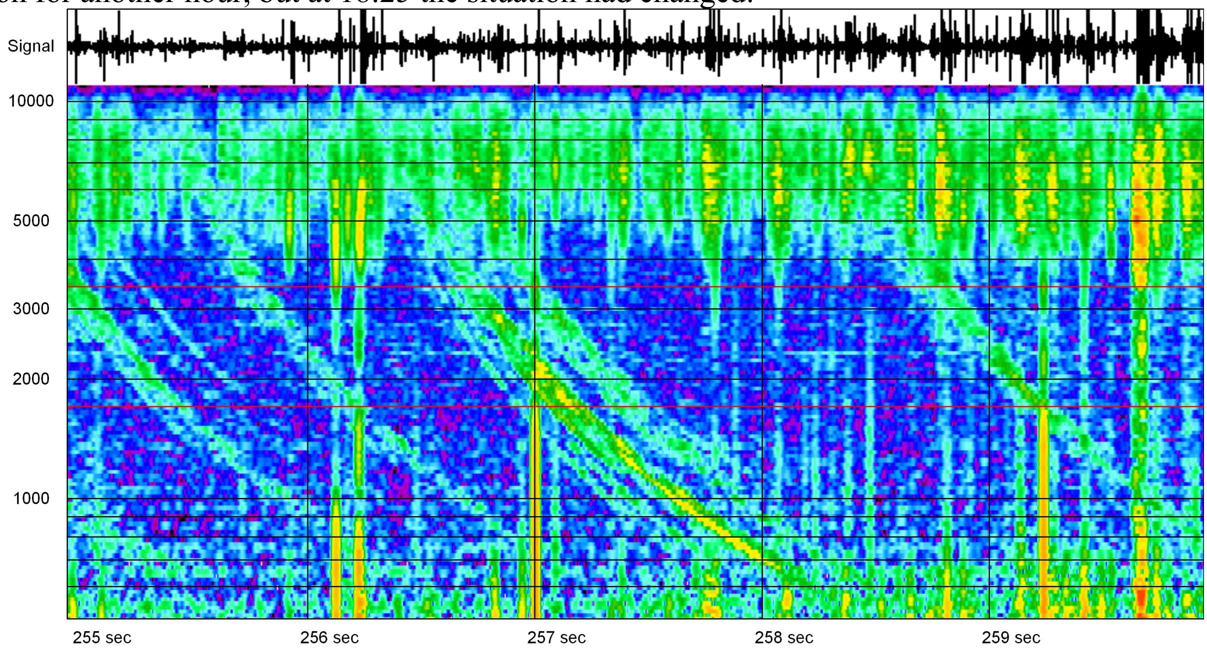
One notes that it seems to split up at its low frequency tail into three components. Such a specimen is quite prominent when directly heard.

As any observer one has to resist the temptation to display and discuss in detail of every single whistler one has recorded … so let us be reasonable and get on … for the next three hours, I could hear this rich mixture of whistlers, faint and loud, single or multiple, short as a mere hint or long reaching low tones. At 16:14 – on a quiet part of the beach itself – I picked up two other nice specimens: Both are composed of several signals. The first one starts at 4000 Hz and reached down to 1000 Hz, but with a gap near 2000 Hz. The second group starts in the same way, but after the gap at 2000 Hz it does not come back with a low-frequency tail. This may tell us that the duct for the whistler was subject to rapid changes.
There is also an interesting optical illusion: It might appear that the second group decreases more rapidly in frequency, but if one compares the slopes of the features at the same frequency, they turn out to be identical.



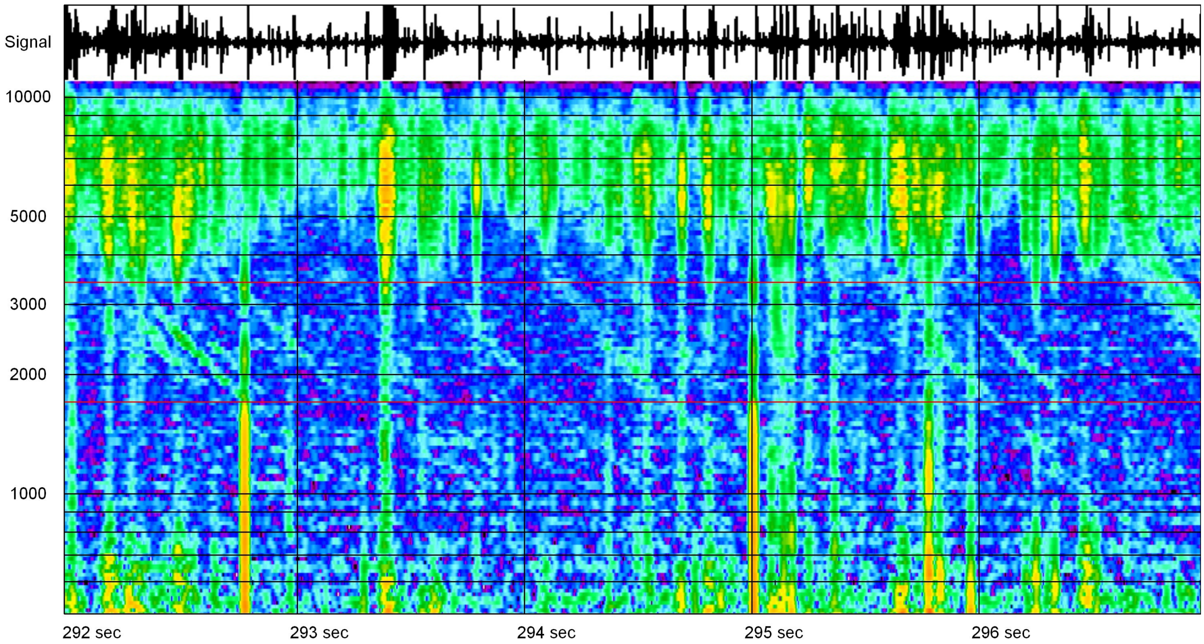
. **A long multiple-component whistler at 88 sec after 16:14 CEST reaching down to 1000 Hz, followed by a shorter one**

At this time, there were numerous faint and quite loud whistlers, but most of them were audible only above 2000 Hz, and only rarely one would sweep down to 1000 Hz. This carried on for another hour, but at 18:25 the situation had changed:



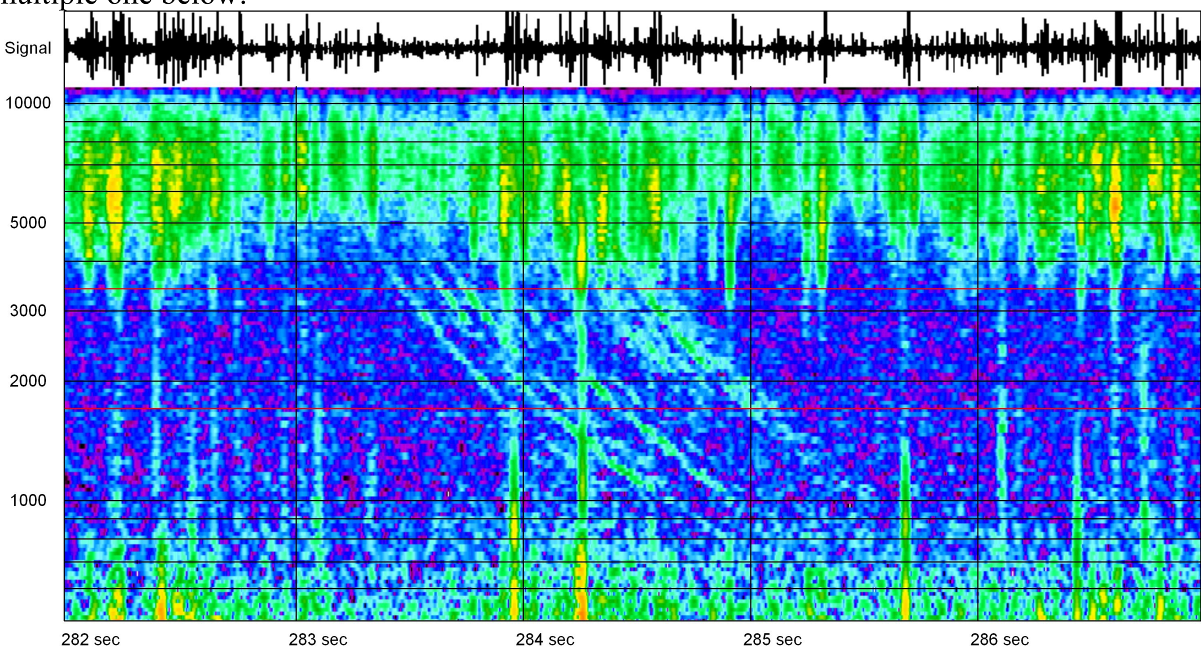
. **A whole fleet of long whistlers at 250 sec after 18:25 CEST, all reaching down to 1000 Hz: one whistler group per second!**

Nearly every whistler could be heard between 5000 and 1000 Hz! Also, they were rather strong, coming about every second. Moreover, despite some hum background – fortunately limited to below 500 Hz – I could hear many faint whistlers piling on top of each other. An example of a swarm of faint whistlers is shown below



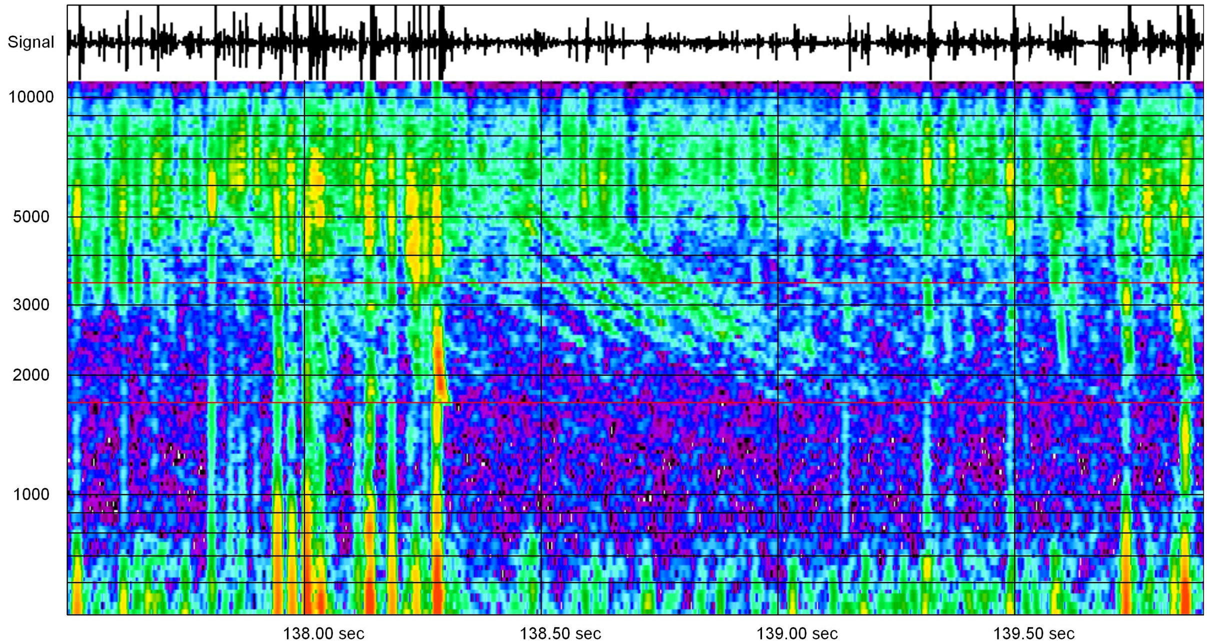
. **A swarm of faint whistlers at 290 sec after 18:25 CEST**

Later, the counting would reveal 25 whistlers per minute. This was the peak of the day's activity! Since the present station was not free of hum, I hasted to carry on through the next settlement and reach my favourite low-noise site at the end of the dyke at 19:28. The situation had changed a little, as the strong and long whistlers had become less frequent, there were quite a few with almost pure-tone, and I captured many with fine structure such as the multiple one below:



. **Whistler with multiple components at 280 sec after 19:28 CEST**

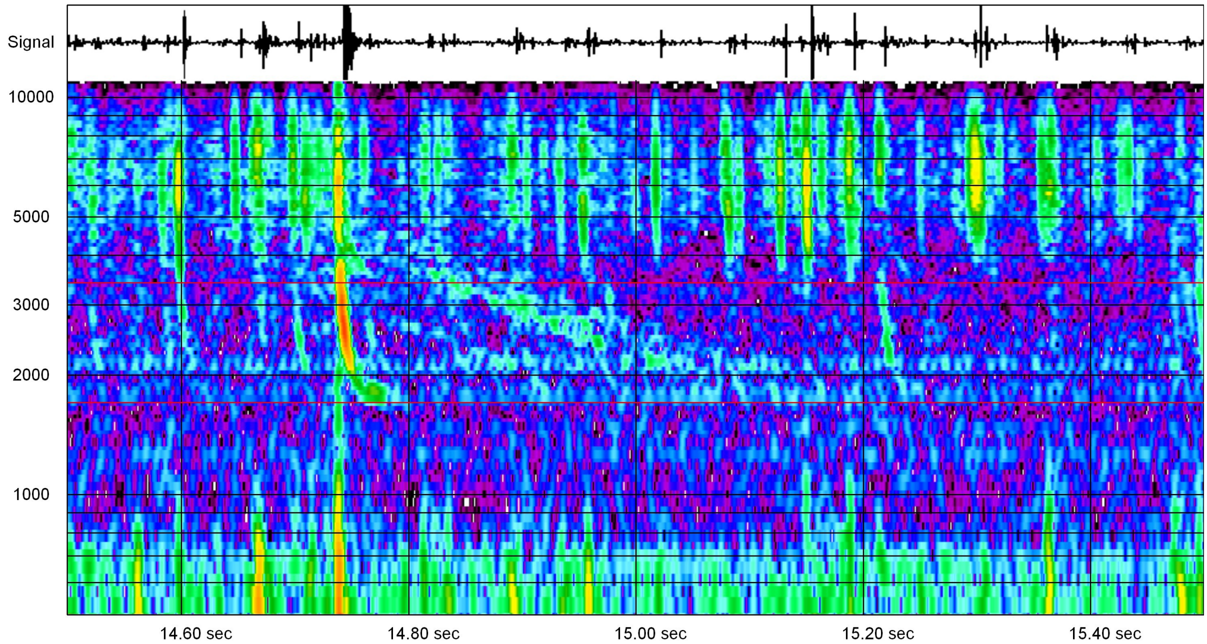
By now, most whistlers were audible in the frequency range from 4000 to 1500 Hz.
One and a half hour later, shortly after sunset, whistlers had become much rarer, and the fainter ones had to compete with the tweeks which became louder.



Strong tweek and faint multiple component whistler at 138 sec after 21:01 CEST. Note that the time axis is expanded to show the tweek

One of the few whistlers I could hear was a rather hissy one, composed of perhaps ten components, which also appear to have different slopes. Just before it there is a strong tweek whose frequency tails off somewhat below 1700 Hz – which would imply a height of the ionosphere of slightly below 300000 km/s / 2*1700 Hz = 88 km.

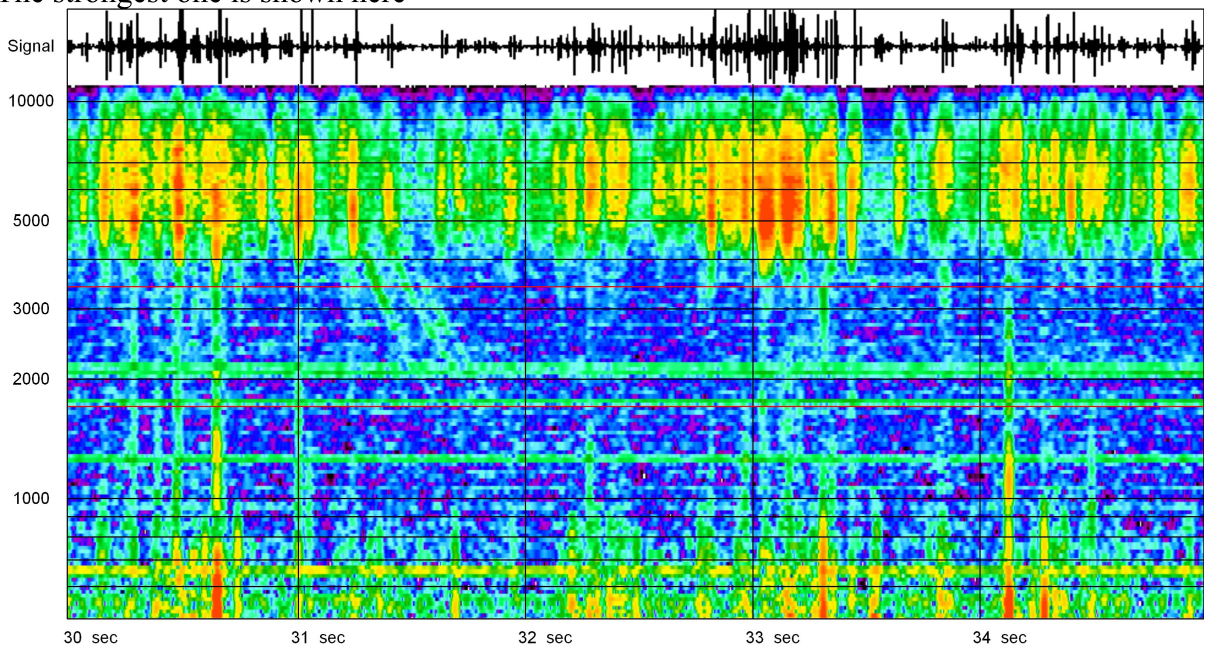
This was my last station on the beach. I took the bus home, but being too curious I went out after midnight to the meadow in a nearby park for another look (and with a fresh tape cassette). The whistler activity was still continuing at a lower intensity, no low frequency tails were heard.



Strong tweek and faint whistler shortly after 01:10 CEST.
The time axis is expanded and the signal level was changed to bring out the features.

Tweeks had become prominent, in the example above, a strong tweek occurs just at the start of a faint whistler. It also shows a trail at 3400 Hz, i.e. twice the cut-off frequency.

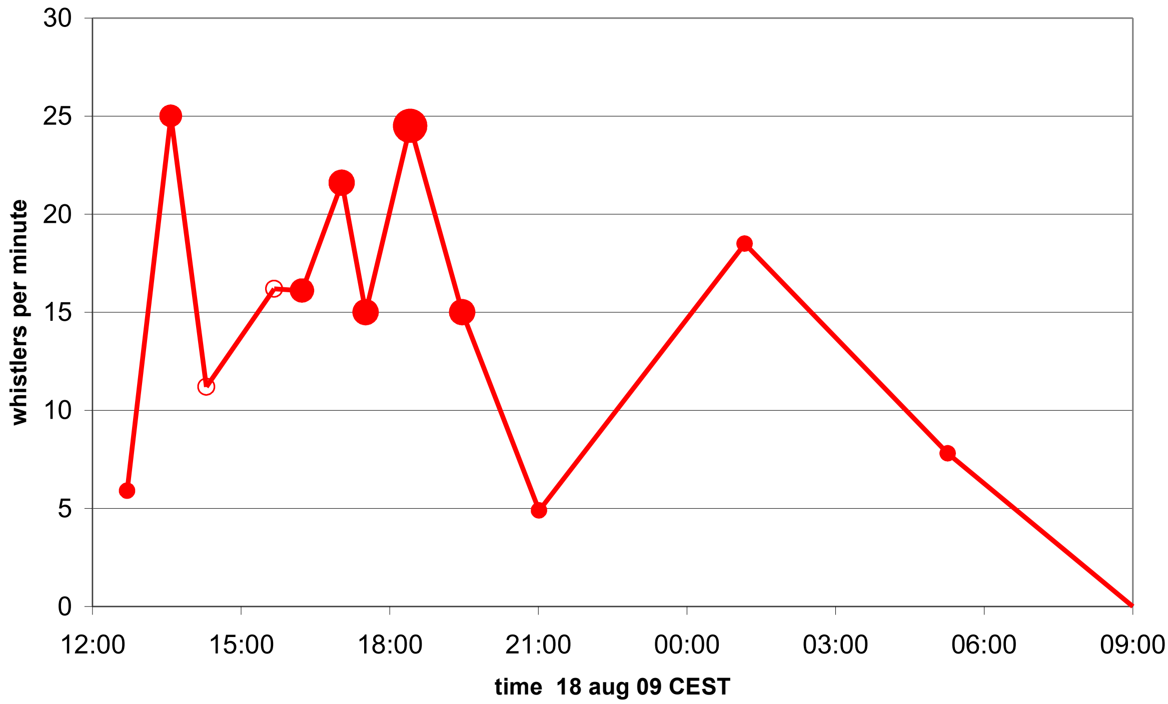
Early next morning, I went to the park again, only to find that the whistlers were still coming. The strongest one is shown here



The strongest whistler shortly after 05:16 CEST.

It was similar in loudness and frequency range as the whistlers heard at the start of this long day of VLF listening! I went back home and into bed again. At 09:00, after I woke up and had breakfast, no whistler could be heard any more! Also, with the rising sun, the tweeks had gone. After an eventful time, we had gone back to normal!

Later, by listening to the audio files, I counted all the whistlers and computed their number frequency of them. However, for a first look I neither distinguish multiple whistlers nor the ones which reach low frequency. The result is shown below:



The evolution in time of the whistler number frequency. The size of the data dots indicates the fraction of whistlers tailing into low frequencies. Open circles mean a location with appreciable hum background.

The data for 14:18 and 15:40 – marked by open circles – was taken with appreciable hum background, which would make it difficult to hear any faint whistlers. The curve traces only one aspect of the whistler activity. A couple of strange effects can be observed: the high number at 13:35 was obtained at a site with appreciable hum, at which one should expect to miss some whistlers. On the contrary, the low count rate at 21:00 was done at a low-noise location! This indicates that the count rate shows the lightning activity at the source, but not really when the conditions are favourable for the radio impulse to travel to the other hemisphere as a whistler. Thus, the higher rate at 01:00 might simply mean that the thunderstorms in southern Africa had regained in strength since 21:00.

Nonetheless, it is interesting to compute the total number of whistlers I could have heard if I had kept listening. Let us assume an average rate of 10 whistlers per minute. Over a total time of – let's say – 17 hours, we get about 10000 whistlers!

The high point of this activity certainly was at 18:25, with a high count rate, but also with almost all whistlers consisting of long and complete sweeps in frequency, down to 1000 Hz. During this day, I could observe that whistlers first appear audible near 3000 Hz and are first limited to a short sweep, such as between 4000 and 2000 Hz. Then, the lower limit frequency seemed to have gone down, and whistlers became not only more numerous, but also more spectacular and louder. Eventually the phenomenon slowly disappeared, their sweep range again became more restricted, their numbers and loudness came down, and eventually whistlers were gone. Perhaps it is the lower limit of the frequency sweep, or the range of the swept frequency, or the loudness which tells something about when conditions are right for lightning to produce whistlers. In the above plot the size of the data dots gives a rough impression of how frequent the long-sweep whistlers were. But this is not quantitative … something to be looked up in the next round!