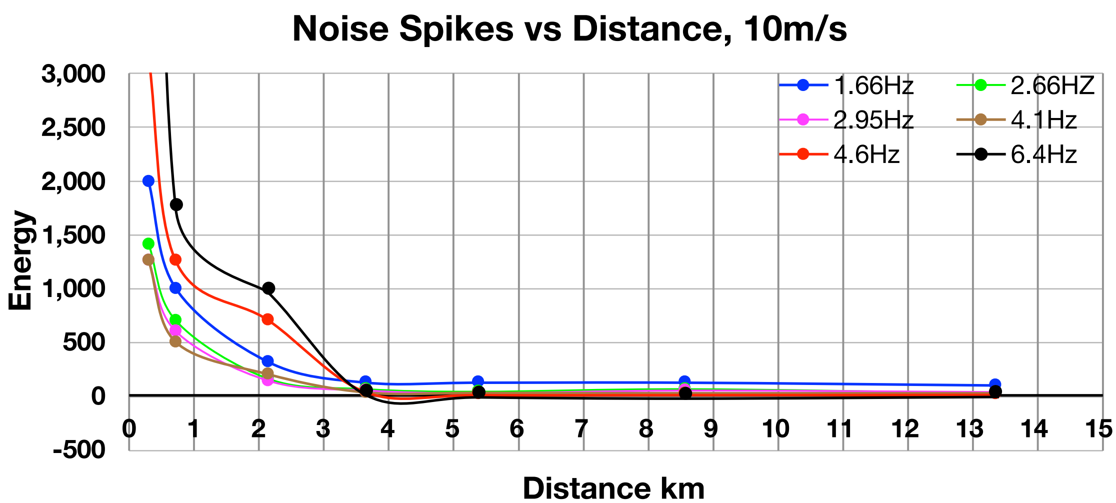
JOINT REVIEW OF REPORT BY DRS. FABIAN LIMBERGER AND GEORG RÜMPKER

By: Gerardo Suárez, Instituto de Geofísica, UNAM and Michael Hasting, President and CEO, Hasting Micro-Seismic Consulting, Inc.

The following are our observations and comments on the report provided by Drs Limberger and Rümpker to CWP on the review of the seismic data acquired in the Eskdalemuir region in 2022 and 2023 and particularly the new Crossdykes wind farm which is located 15kms from Eskdalemuir.

A total of 10 stations were deployed for data acquisition; 6 of these were used for this report to evaluate the attenuation of noise generated by the Wind Farms (WF) with distance. This study focuses on the key issue of measured attenuation distances of noise induced by Wind Farms (WF) in the EKA array.

1. There is a sharp reduction in seismic energy as a function of distance from the WF. This is observable in the frequency of interest to AWE, of 2 to 5 Hz. Looking at the energy from each of the stations used for this study, along with data from the EKB1, the following plot shows how the noise decays rapidly as a function of distance:



Note that by about 3.6km the energy at all frequencies is at or near the background noise level.

2. The noise reduction (expressed as Power Spectral Density, PSD), at a distance of approximately 3.6 km is at least two orders of magnitude (100 times) less when compared to the seismic noise energy near the WF in the frequency band of interest.

3. At a distance of more than approximately 5 km, the effect of the WF is not observed, regardless of whether the WF is operational or not. The noise reduction in this case is approximately three orders of magnitude (1000 times) less when compared to the seismic noise energy near the WF, in the frequency band of interest.

4. The spectrograms shown in Limberger and Rümpker´s report clearly show this effect. One can clearly see that when the WF is operational, at stations 6v71 and EKB1, the noise from the WF is not observable in the spectrograms. Additionally, as has been reported previously, anthropogenic noise at ~6.4Hz in both stations is clearly evident, when the WF is off. Also, this signal does not appear at all-times when the WF is operational indicating a secondary source not related to WFs.

5. These results underpin that seismic noise is highly attenuated beyond ~5 km. Thus, any WF proposed beyond that distance would not affect the operation, mission, and detection capabilities of EKA.

6. The results clearly show a general increase in background seismic noise as a function of wind velocity which cannot be correlated to WFs. This point has been made in our previous reports and dismissed by AWE.

7. There is a difference in background noise at EKA between day and night. This shows that anthropogenic noise, probably induced by logging activities, causes a diurnal effect. This cannot be caused by WFs, which operate 24/7.

8. As shown in previous studies conducted by CWP in collaboration with HMSC, the installation of seismic sensors in boreholes will add an additional advantage in reducing noise that would presumably come from wind, quarrying, timber logging, or WF noise.

Conclusions:

Results from this data set acquired in 2022 and 2023 support data observed in 2025. The data show high background noise levels during high wind conditions at both the temporary stations as well as at the Eskdalemuir array. The data from the experiment conducted by Limberger Rümpker clearly show that the noise generated by the WFs is totally attenuated at the temporary station located at a distance of 5.4km; it should also be noted that even at 3.66km the noise is down by at least 2 orders of magnitude (100 times).

The spectrograms shown in this report provide clear and conclusive evidence that on a high wind day of 10m/s, there is no impact on the Eskdalemuir Array resulting from a WF at a distance of over ~5.4km. Beyond this distance, WF noise is simply not observable. Thuus it would not cause any operational problems at EKA. This observation is similarly highlighted in the spectrograms shown in the previous reports from 2025 data, provided by HMSC.

Again, these spectrogram data show the clear presence of anthropogenic noise that is not associated with WFs in the bandwidth of interest to AWE.

We agree with Drs. Limberger and Rümpker's conclusion and observations that their data show that WFs and their turbines do not show significant noise level at EKB1, the closest station to the WFs. As this is real world data and not results based on modeling, the data clearly show that there is no material impact of seismic noise induced by WF at distances over 3.6km; beyond 5.4km, seismic signals associated with WFs are not observed.

In conclusion, these new results clearly show that WFs do not degrade EKA data quality on high wind days when they are producing near the maximum power output capability and, potentially, producing the largest noise levels. The data presented in the study patently show that there is no scientific or data-based rationale to control or prevent wind farm development beyond 5km, from any sensor comprising EKA.

Respectfully,

Gerardo Suárez

Michael Hasting

APPENDIX

Re-Analysis of seismological data to characterize the decay of ground motions induced by wind turbines

by Dr. Fabian Limberger & Prof. Dr. Georg Rümpker

Motivation

An investigation of the decay of wind-turbine (WT) induced seismic signals can be done by analyzing noise levels recorded with seismometers as function of frequency, distance to the wind farm (WF), and wind speed. The computation of power spectral densities (PDSs) of continuous seismic recordings is highly suitable for this task.

Processing

The analysis of CWP and EKA seismic recordings involved cutting (up to) six months of Z-component ground motion data into 10-minute PSDs and binning the spectra to wind speed measured at the Haggis Side meteorological tower. The 25% highest noise amplitudes were considered as outliers and were excluded to avoid bias from short-term-signals not related to wind turbines. PSDs were then sorted by daytime and night time (6 pm – 6 am) and averaged per wind speed group to obtain statistically robust distance- and wind-dependent spectra.

WT-induced peaks are generally defined by four criteria

(1) Clear Peak detection close to the WF.

(2) Systematic decrease of signal energy with increasing distance to the WF.

(3) Increase of signal energy with increasing wind speed.

(4) No significant signal energy during low-wind conditions, except close to the WTs due to slight tower swaying at low wind speeds even without WT rotation.

CWP data

Recordings along the profile stations provided by CWP show near-field spectral peaks between 1 and 10 Hz fulfilling the mentioned criteria: 1.14 Hz, 1.63 Hz, 2.28 Hz, 2.72 Hz, 3.41 Hz, 3.89 Hz, 4.6 Hz, 6.4 Hz, and 7.7 Hz. Peaks between 2 and 4 Hz are insignificant at larger distances due to low initial emission amplitudes. Peaks above 4 Hz have high near-field amplitudes but damp quickly with distance along the profile. WT signals remain observable at station 6v71 (5.4 km) with very low amplitudes, but vanish at 6v70 (8.6 km). Stations 6o87 (300 m), 6w19 (6.7 km), and 6o89 (10 km) were excluded due to high noise (likely by very local wind-dependent noise sources). Day/night comparisons systematically show no significant impact on the peaks, while the overall noise level is slightly reduced. This indicates WT-dominated noise fields in the near-field at both day **and** night.

EKA data

Recordings at EKB1, EKB2 and EKB3 reveal peaks ≥ 3 Hz, which are very sharp and are present at low and high wind speeds, which is untypical for WT-induced signals. Suspicious peaks at 2.10, 2.66, and 2.95 Hz share some WT-like characteristics but are not confirmed at near-field stations. The near-field peaks at 1.14 and 1.63 Hz are not detected at EKA stations. A minor peak at approx. 1.33 Hz is observed, however, this peak cannot be confirmed by near-field measurements. Day/night comparisons show significantly lower noise at night, indicating that the noise field at day is dominated by anthropogenic noise (unrelated to WTs).

Conclusions

(1) Peaks identified near WTs attenuate strongly, being undetectable at 8.6 km and only weakly visible at 5.4 km.

(2) Distinct peaks observed at the EKA stations do not meet WT-signal criteria and cannot be reliably related to the measurements in the near field of the WTs.

(3) Day/night analysis indicates WT-dominated noise fields up to ~5.4 km in the vicinity of the WF at day and night, while anthropogenic noise (not WT related) dominates at EKA during the day.

(4) Short-term analysis using spectrograms of signals measured during wind-turbine operational changes at high wind speeds does not show significant changes of the noise level at station EKB1. Monochromatic noise is visible at EKA stations, although wind turbines are not operating.

Note: All necessary figures are included in the attached presentation.

Report for CWP

Re-Analysis of seismological data to characterize the decay of ground motions induced by wind turbines

by Dr. Fabian Limberger & Prof. Dr. Georg Rümpker

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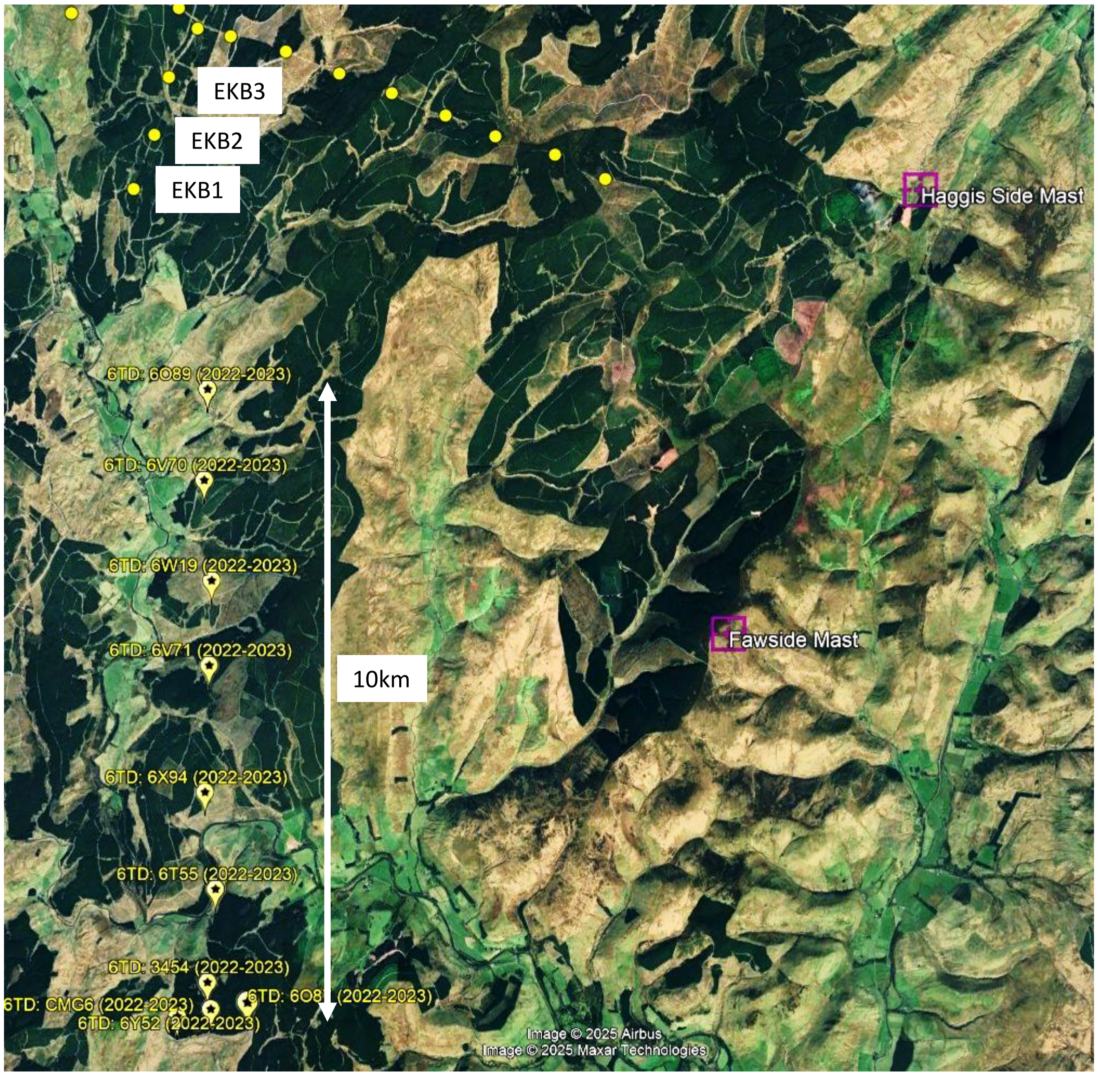
September 2025



WT-induced peaks must fulfill the following criteria:

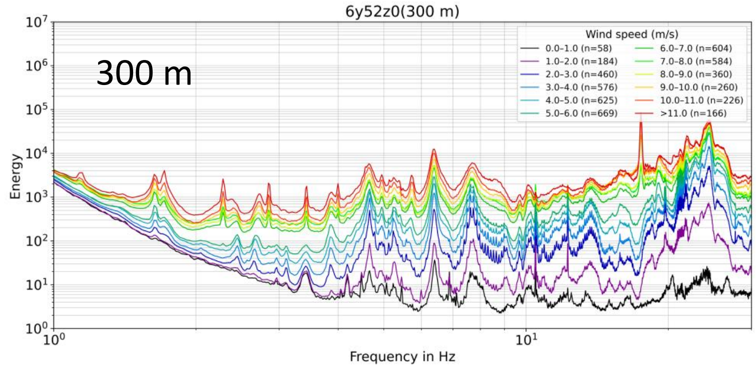
1. Detected close to the WT (300m).
2. Systematically decrease with increasing distance to WTs.
3. Increase with wind speed.
4. No signal energy when there is no wind (except close to WTs, due to slight tower swaying at low wind speeds, even given non-rotating WT)

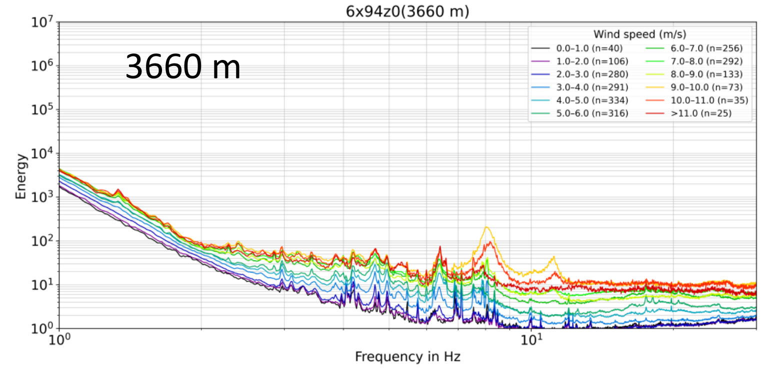
Data processing steps

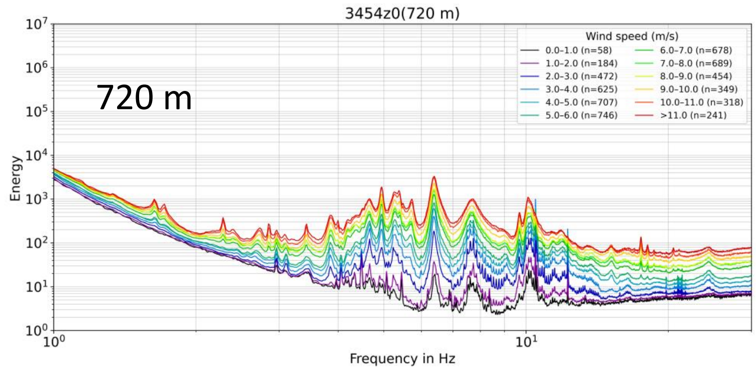
1. Cutting approx. 6 months of data (Z-comp) into 10min PSDs.
2. Bin PSDs to wind speed from Haggis Side met. tower.
3. Remove upper 25% of outliers to avoid bias by short-term non-WT related signals.
4. Sort by day and night (6 pm – 6 am).
5. Average all PSDs per wind speed group to obtain statistically robust spectra.

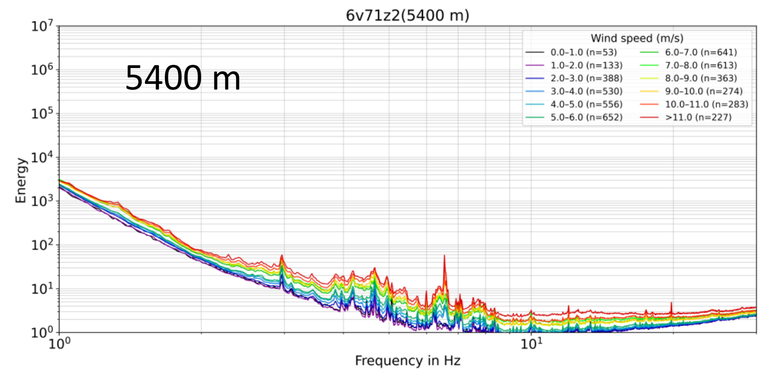
Profile Stations

at night (6pm – 6am)

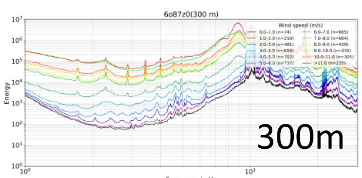


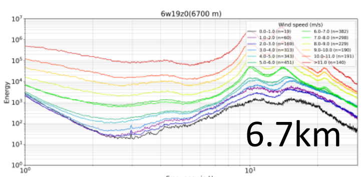


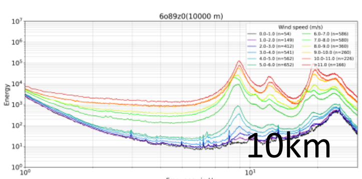


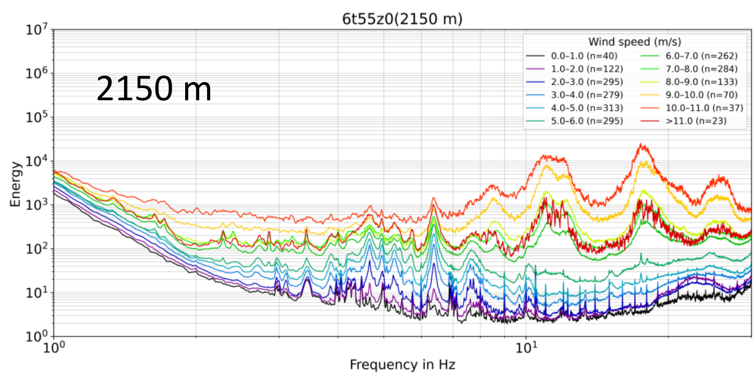


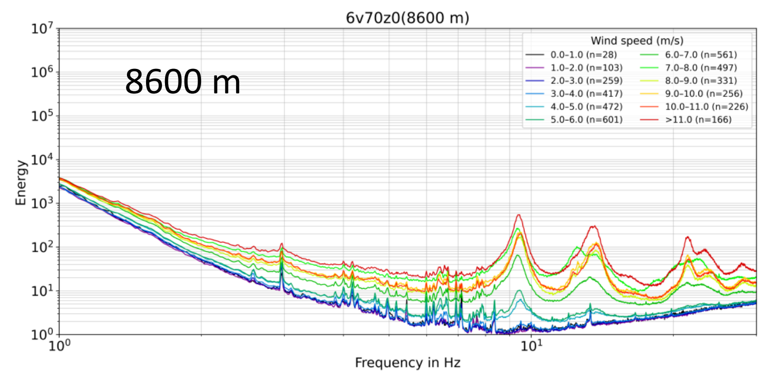
Stations excluded:





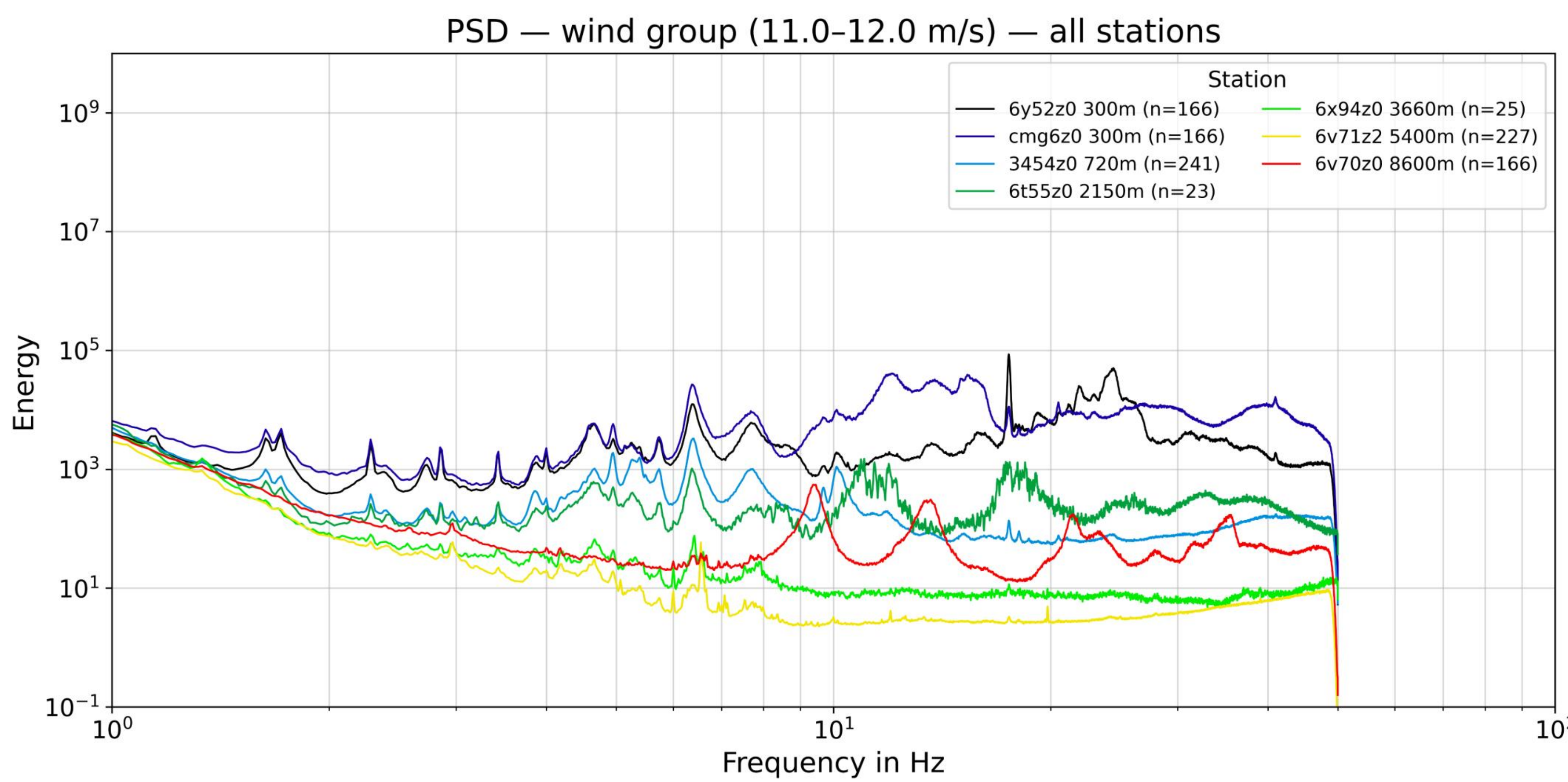




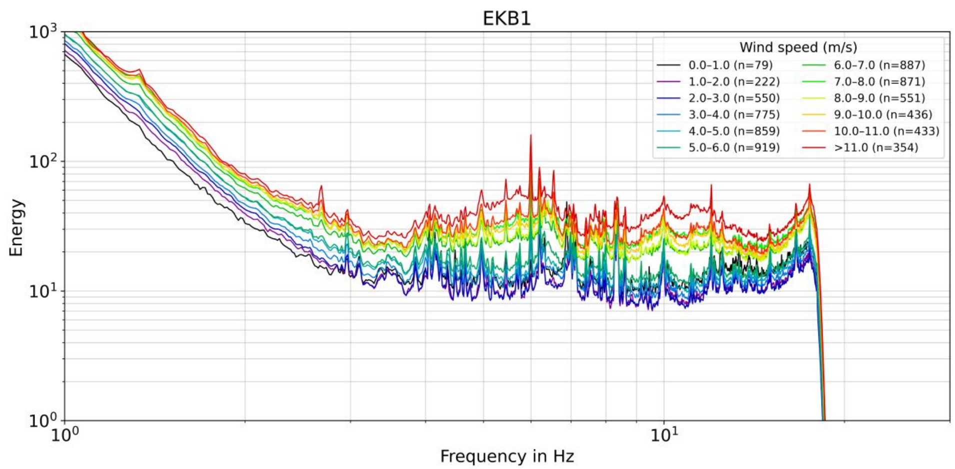


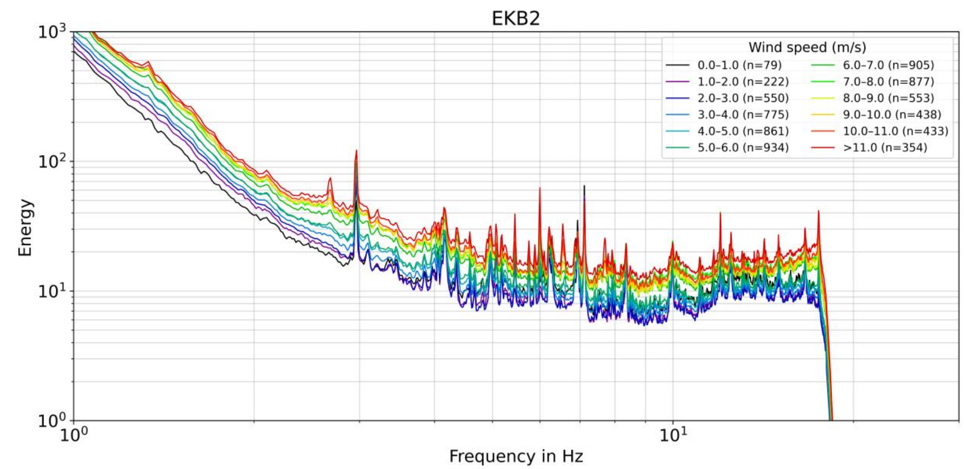
Profil stations sorted by distance

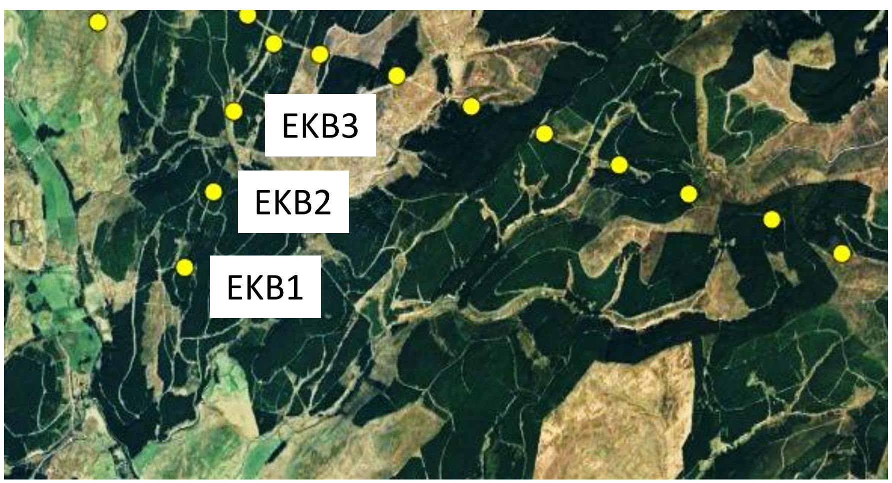
(wind speed = 11 - 12 m/s)

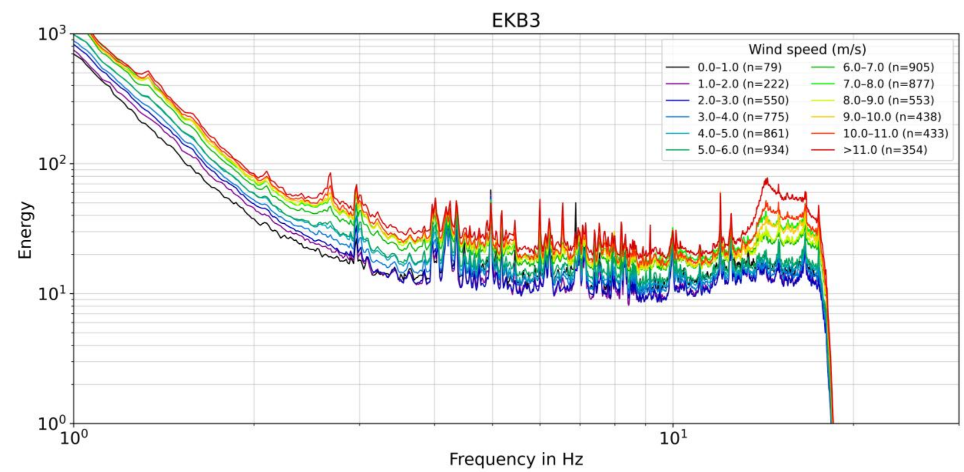


EKA Stations

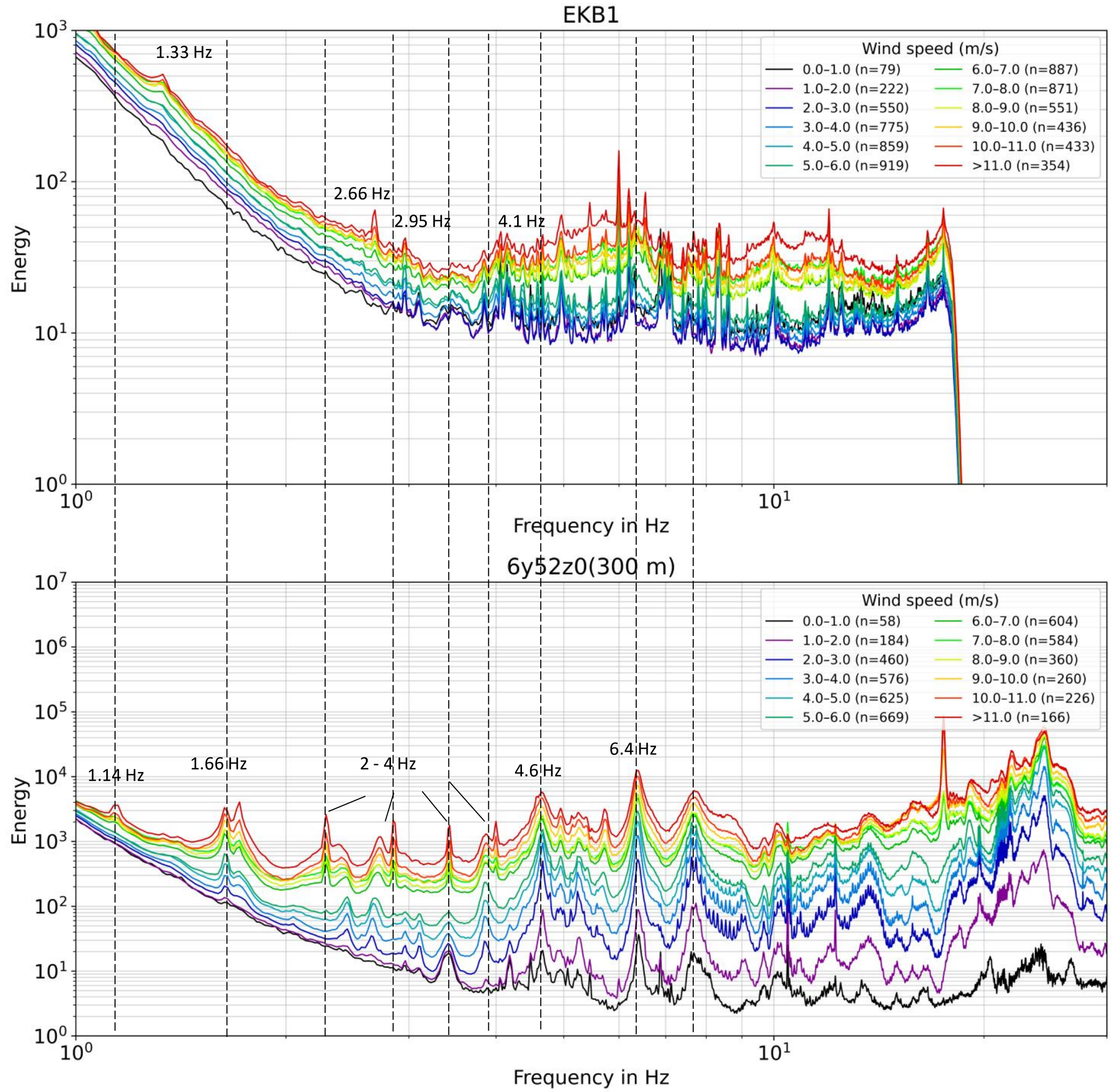






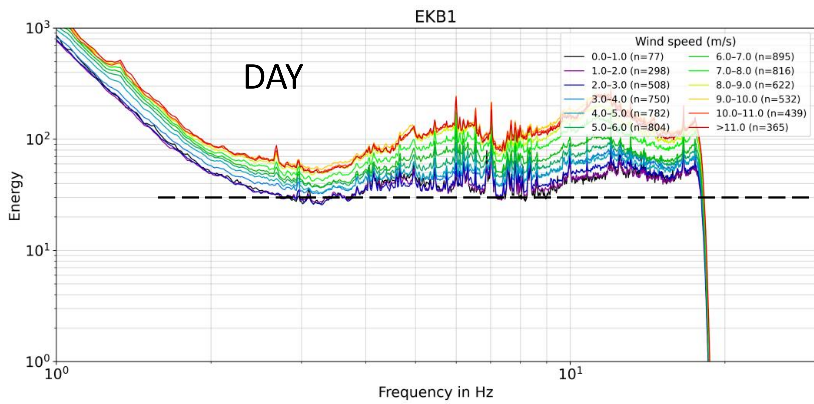


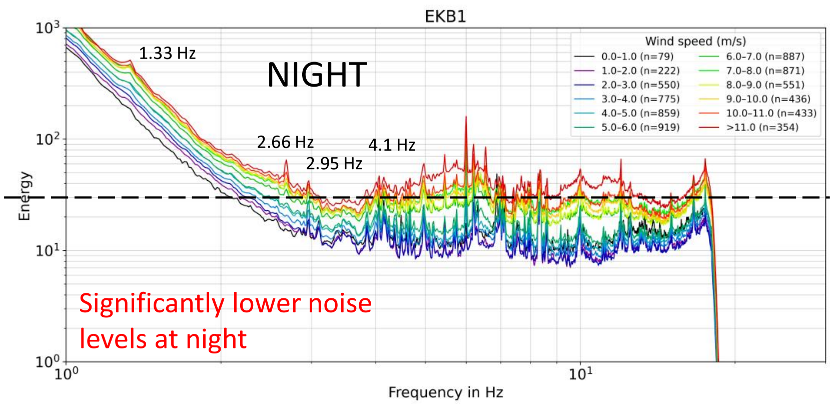
Peak comparison at EKA (far field) and 6y52 (near field)



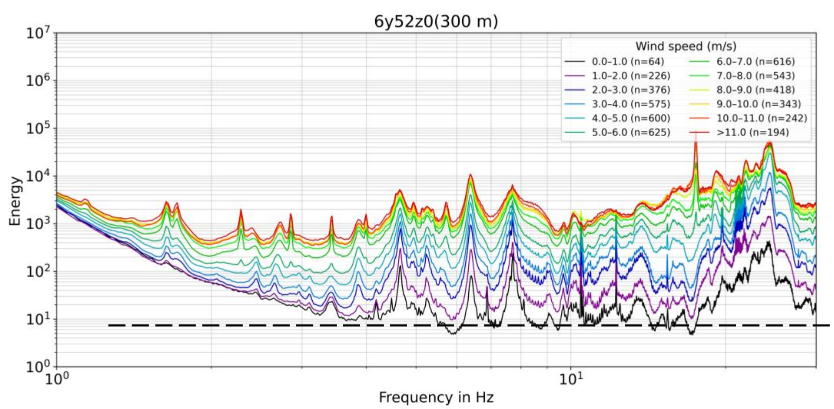
Day / Night effect

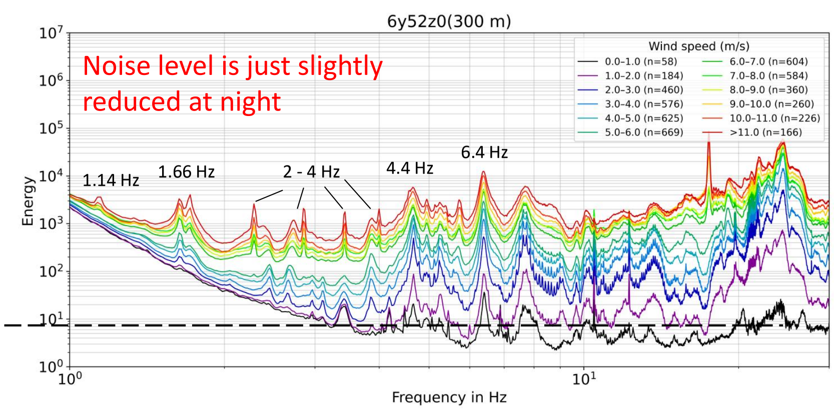
Station EKB 1 (closest EKA station)

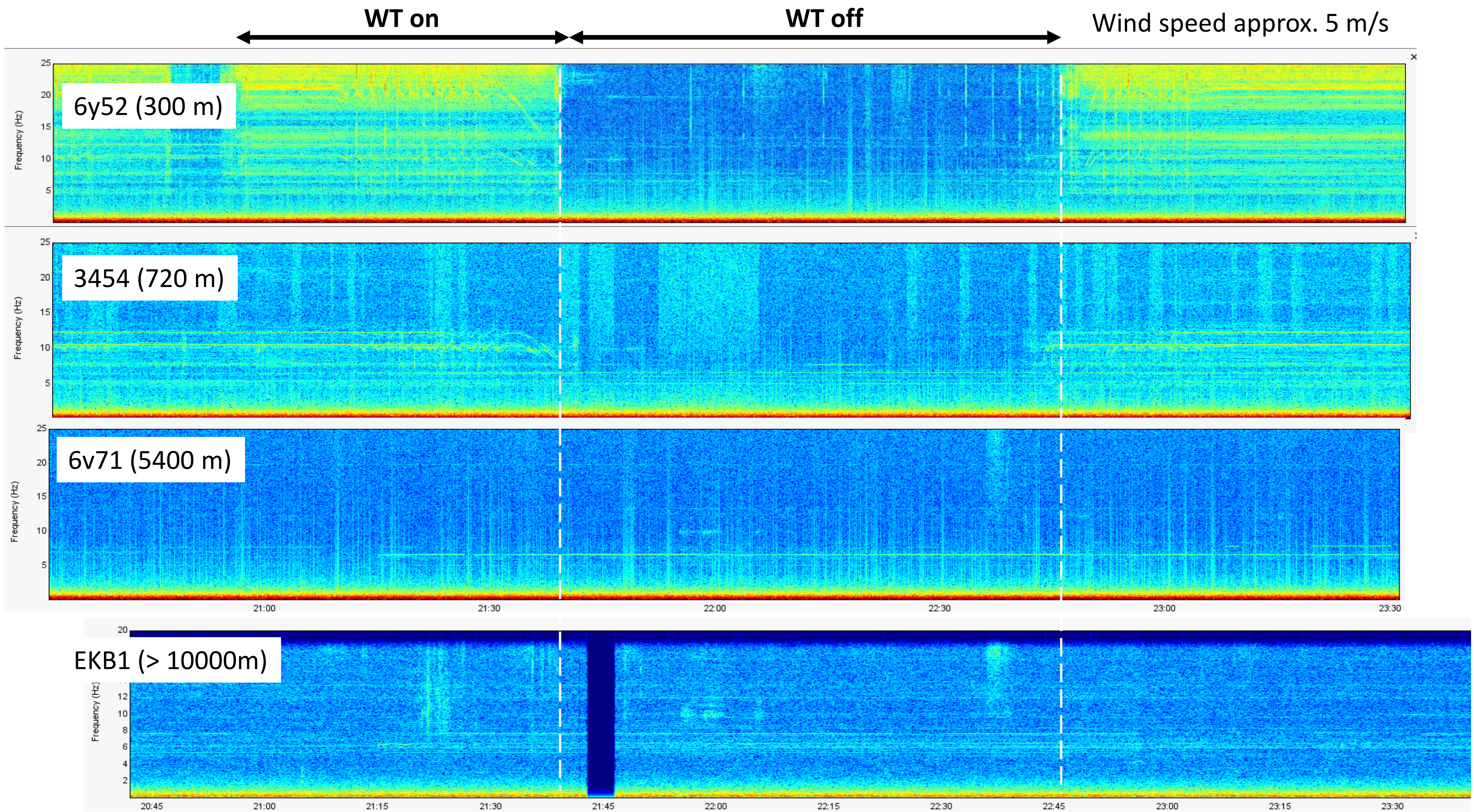


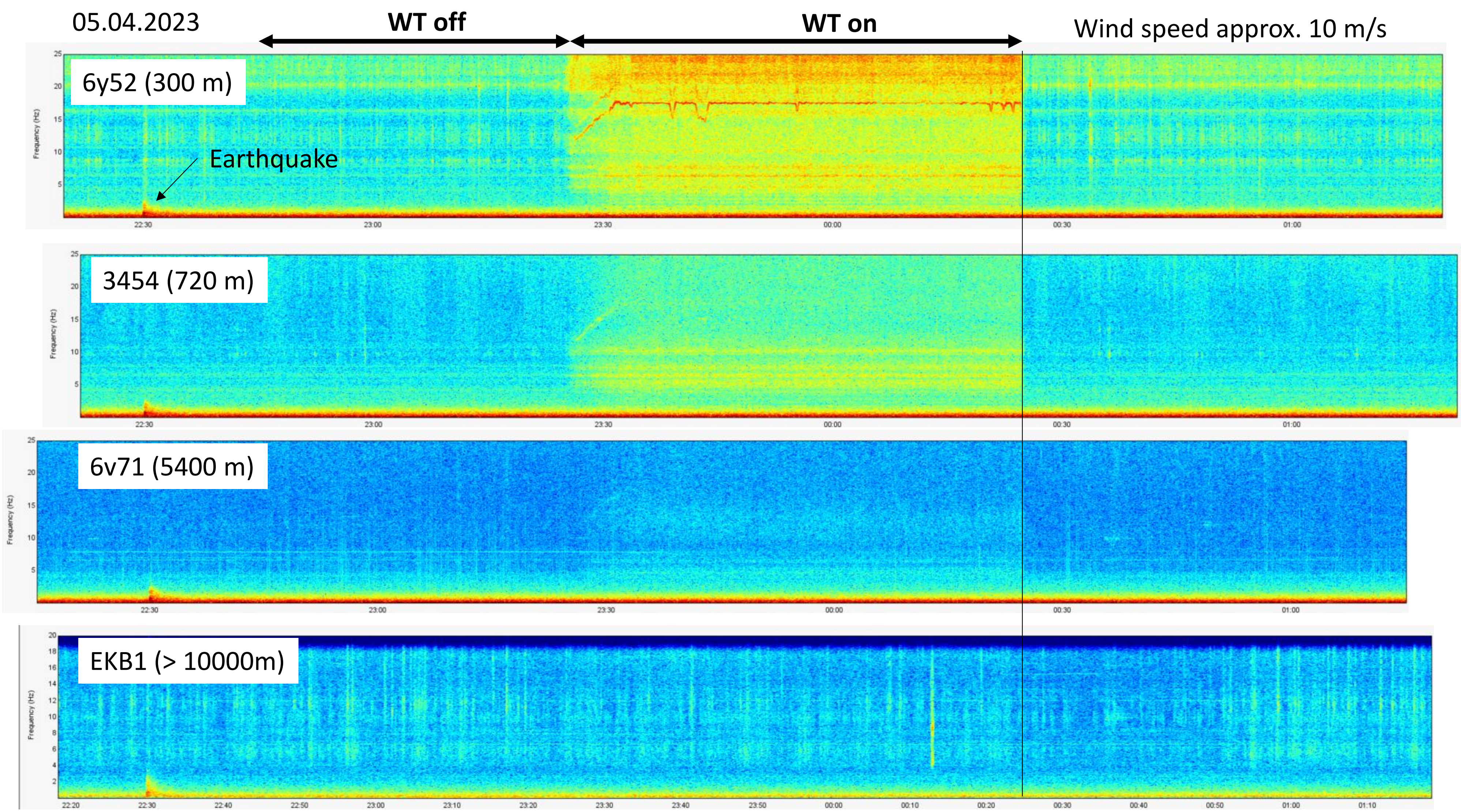


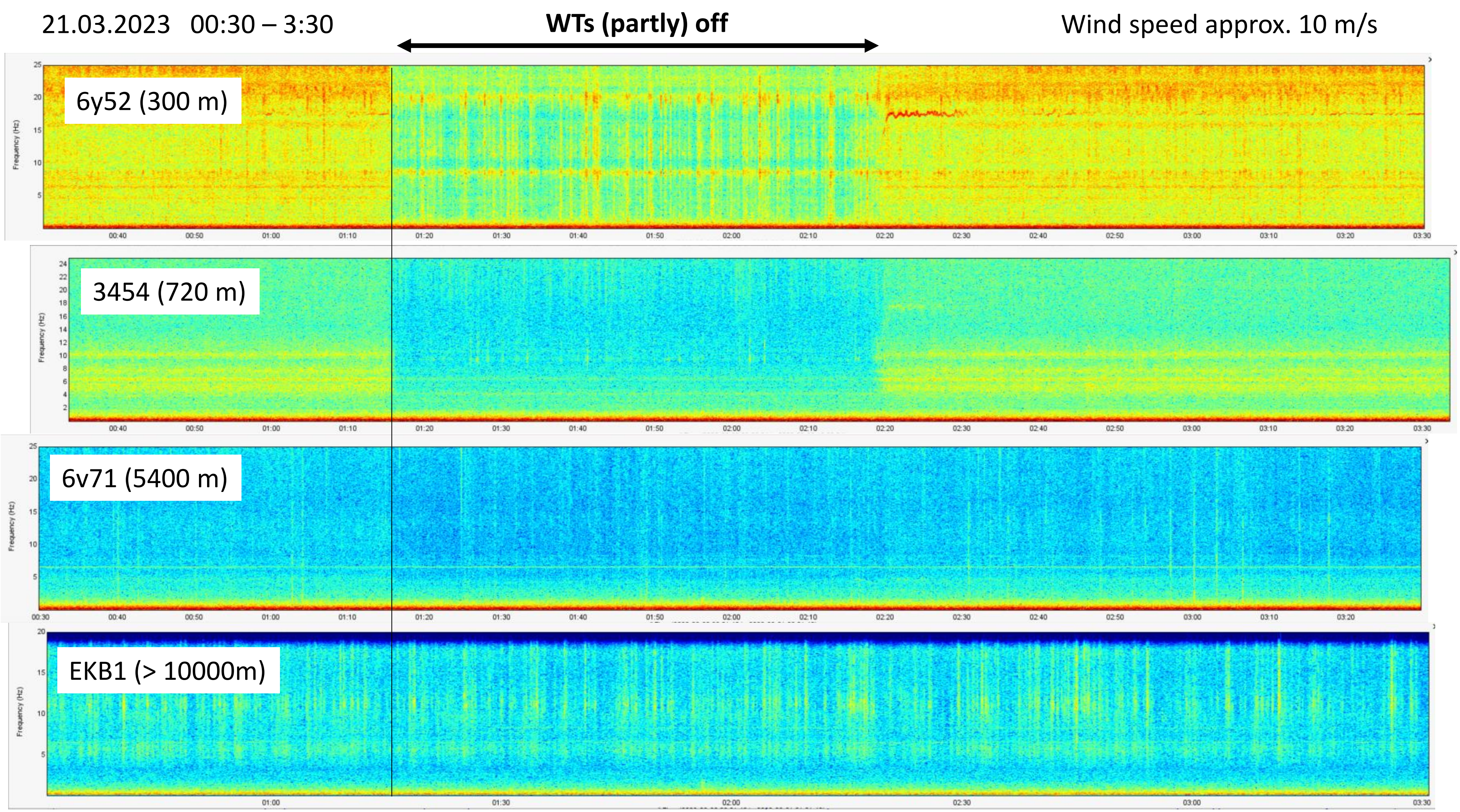
Station 6y52 in 300 m distance






WT on
WT off
Wind speed approx. 5 m/s
6y52 (300 m)
3454 (720 m)
6v71 (5400 m)
EKB1 (> 10000m)
Frequency (Hz)
21:00
21:30
22:00
22:30
23:00
23:30
20:45
21:15
21:45
22:15
22:45
23:15


05.04.2023
WT off
WT on
Wind speed approx. 10 m/s
6y52 (300 m)
Earthquake
3454 (720 m)
6v71 (5400 m)
EKB1 (> 10000m)
Frequency (Hz)


21.03.2023 00:30 – 3:30
WTs (partly) off
Wind speed approx. 10 m/s
6y52 (300 m)
3454 (720 m)
6v71 (5400 m)
EKB1 (> 10000m)
Frequency (Hz)

Main conclusions derived from the data

1. Peaks identified close to the WTs are significantly attenuated at distances of 5.4 km and are not reliably detectable at 8.6 km.

2. Distinct peaks at the three EKA stations EKB1, EKB2, and EKB3 do not fulfill WT-induced signal criteria. None of the peaks can be reliably related to the WT-induced signals measured in the near field.

3. Day/night comparison suggests WT-dominated noise field at day **and** night in the vicinity of the WF (approx. up to the distance of 5.4 km); however, anthropogenic noise dominates at EKA stations mainly during the day (unrelated to WTs).

4. Short-term analysis of wind-turbine operational changes at high wind speeds does not show significant changes of the noise level at station EKB1.