Seismik

providing expert solutions for your passive seismic research needs

The Haag Noise analysis

Seismik s.r.o. for Hydreco Geomec

31/1/2020

Introduction

- The measurement for noise evaluation in Den Haag was executed in the period 21/1 – 24/1/2019 without any serious technical problem.
- Background noise was measured for 16-24 hours at each of the 8 sites.
- The duration of noise monitoring allows comparison of seismic noise levels at these sites. The noise was measured during the work days and includes night and day hours.
- Access to sites was well organized by Hydreco Geomec.

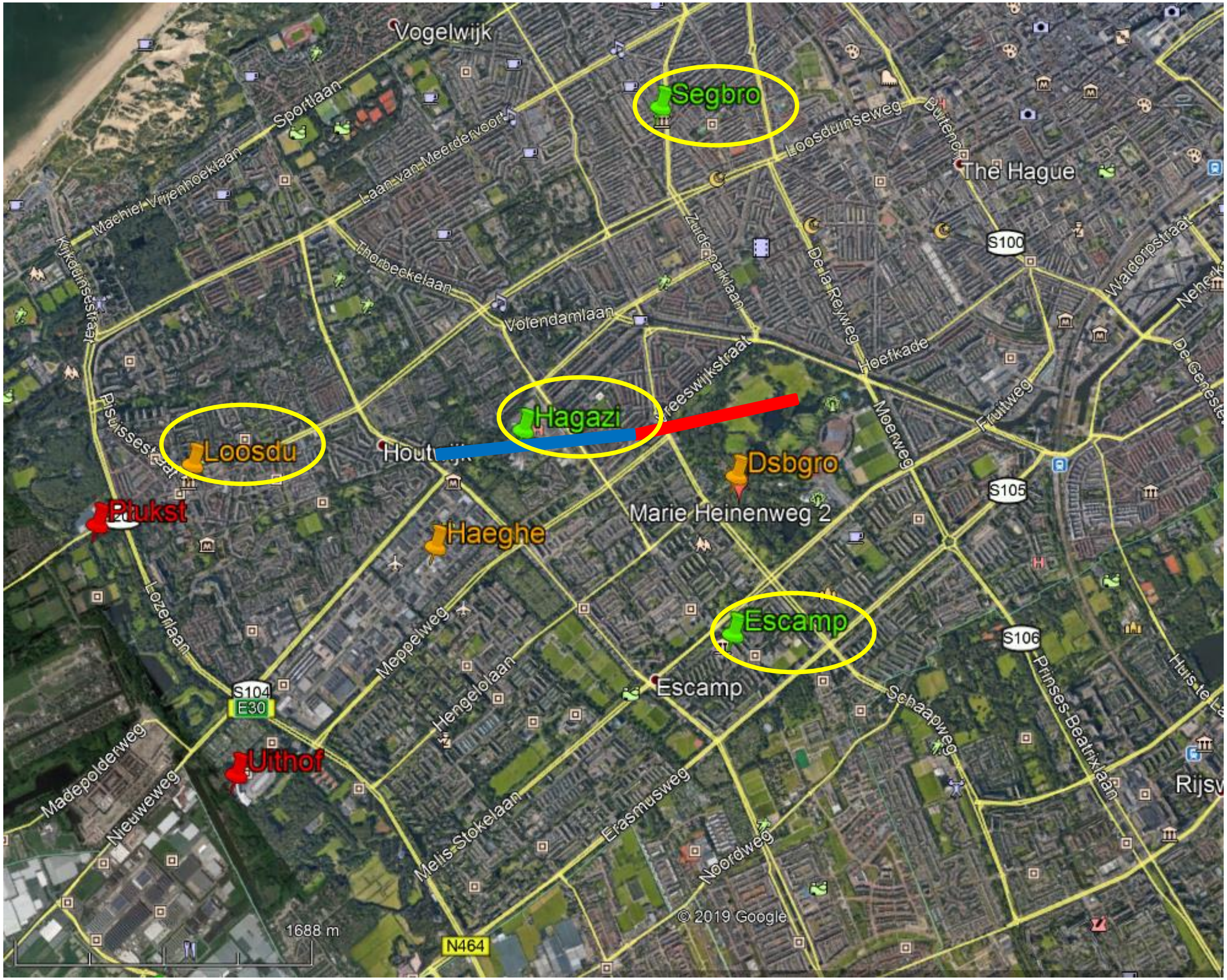
Seismic Noise Evaluation

- The following charts show hourly medians of maximum horizontal amplitudes determined in each 10 s interval.
- The recorded data were filtered with bandpass Butterworth filter between 1 Hz and 50 Hz as this band is the most suitable for the microseismic event analysis.
- Time is in UTC (local Holland time – 1 hour)
- The table on the next page summarizes the list of measured locations

Locations overview

Location	Adress	Shroth name
SDK Loosduinen	Kleine Keizer 3	Loosdu
Stadsboerderij Pluk	Loosduinse Hoofdstraat 1184 A	Plukst
Haga Ziekenhuis	Els Borst-Eilersplein 275	Hagazi
SDK Segbroek	Fahrenheitstraat 190	Segbro
SDK Escamp	Leyweg 813	Escamp
Uithof	Jaap Edenweg 10	Uithof
Haeghe groep	Kerketuinweg 24	Haeghe
DSB groenbedrijf	Marie Heinenweg 2	Dsbgro

Locations overview



- Least noisy locations marked in green
- Medium noisy locations marked in orange
- Most noisy locations marked in red
- Red and blue lines show the paths of the planned geothermal wells
- Marked stations were used for the NetDesign

LOOSDU

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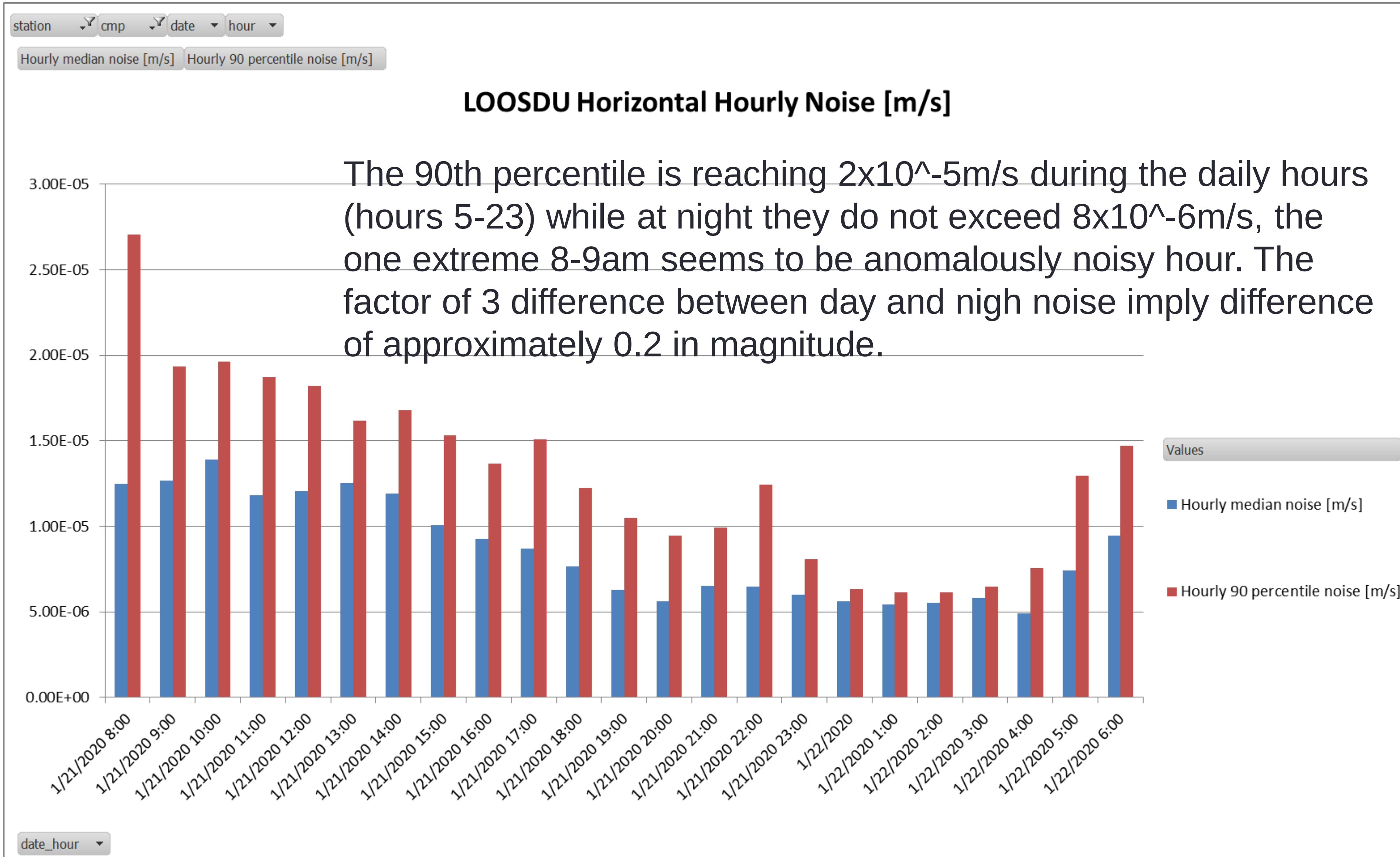
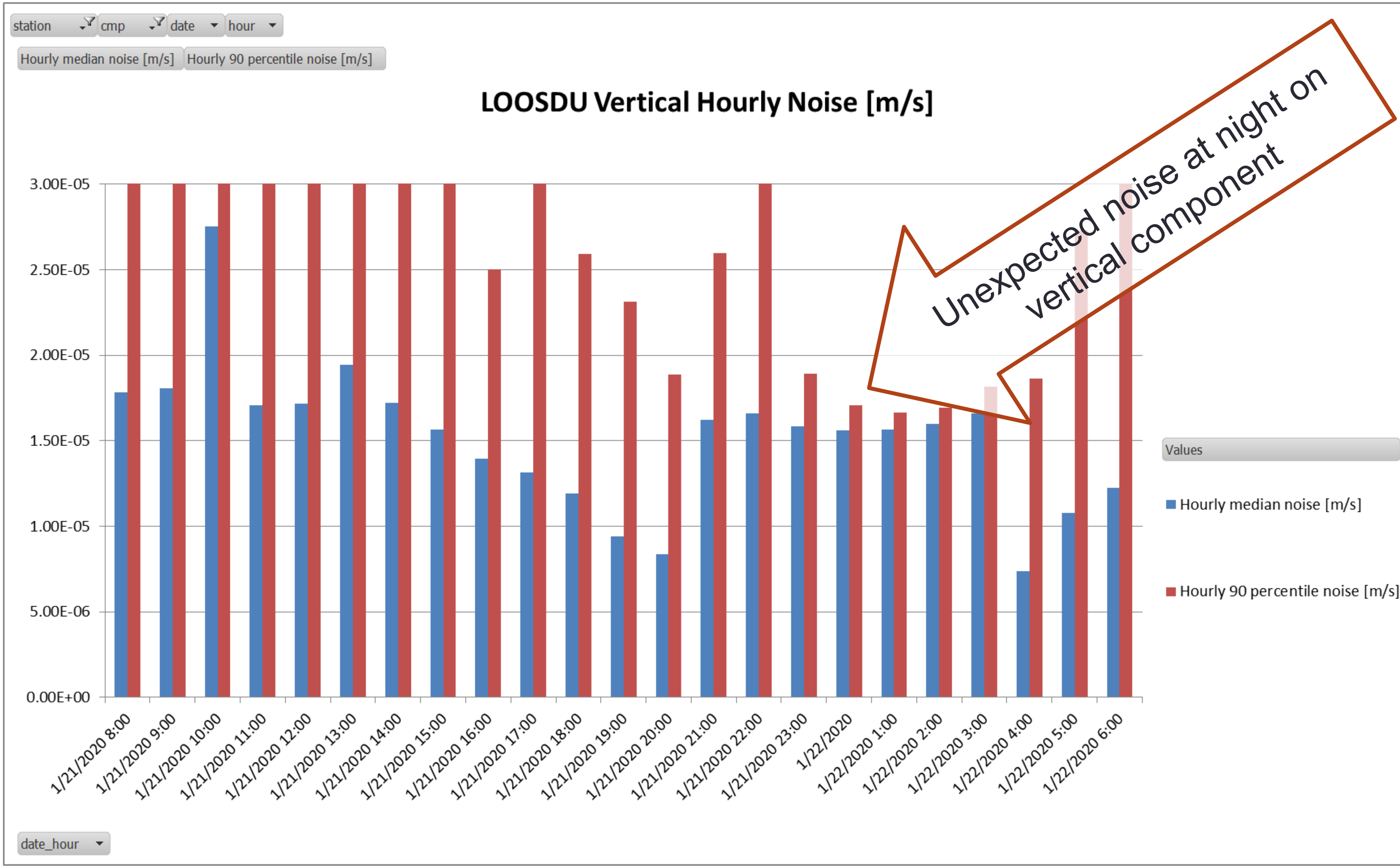


The 90th percentile is reaching 2x10^-5m/s during the daily hours (hours 5-23) while at night they do not exceed 8x10^-6m/s, the one extreme 8-9am seems to be anomalously noisy hour. The factor of 3 difference between day and nigh noise imply difference of approximately 0.2 in magnitude.

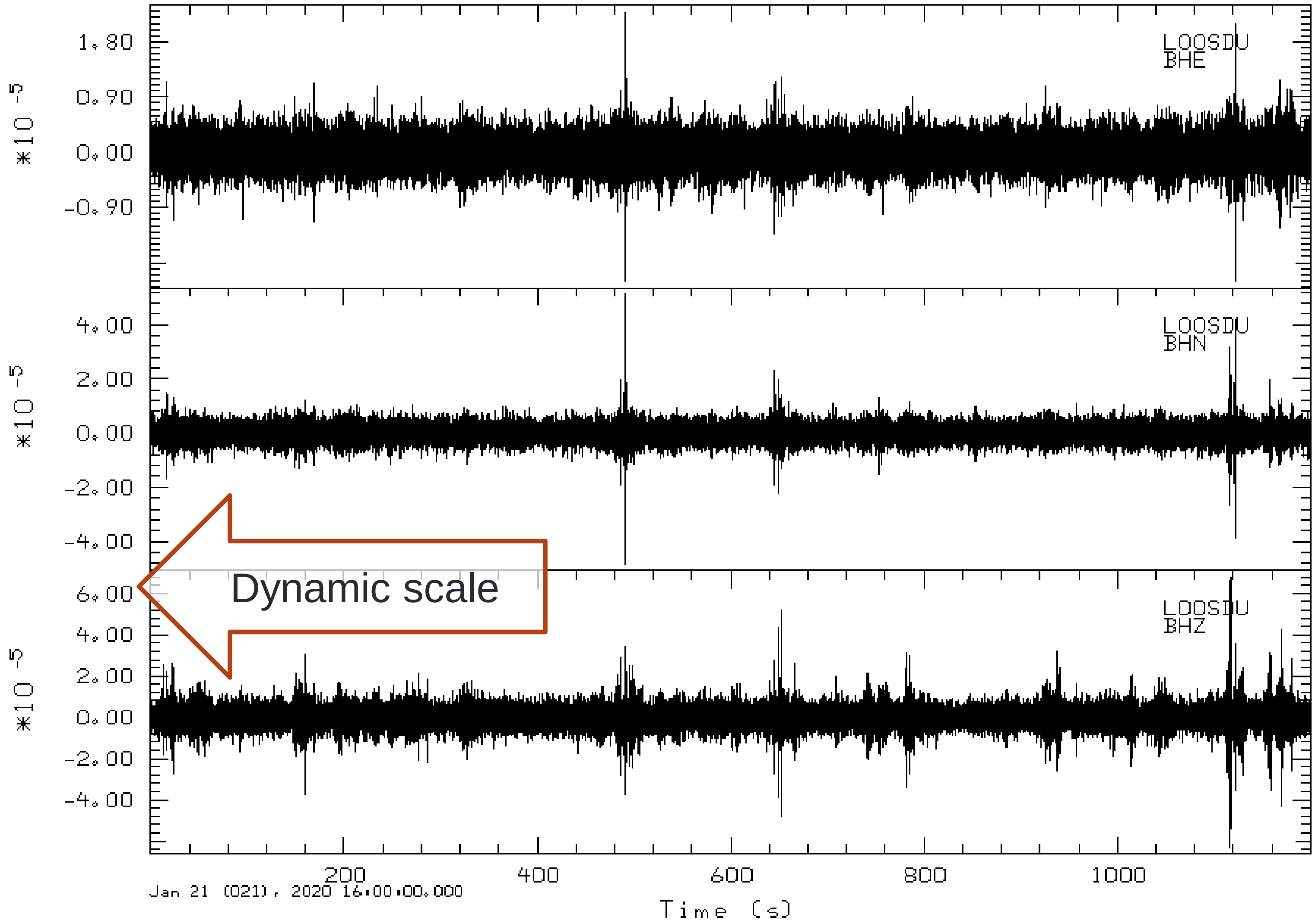
LOOSDU



station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
LOOSDU Vertical Hourly Noise [m/s]
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/21/2020 8:00
1/21/2020 9:00
1/21/2020 10:00
1/21/2020 11:00
1/21/2020 12:00
1/21/2020 13:00
1/21/2020 14:00
1/21/2020 15:00
1/21/2020 16:00
1/21/2020 17:00
1/21/2020 18:00
1/21/2020 19:00
1/21/2020 20:00
1/21/2020 21:00
1/21/2020 22:00
1/21/2020 23:00
1/22/2020
1/22/2020 1:00
1/22/2020 2:00
1/22/2020 3:00
1/22/2020 4:00
1/22/2020 5:00
1/22/2020 6:00
Unexpected noise at night on vertical component
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

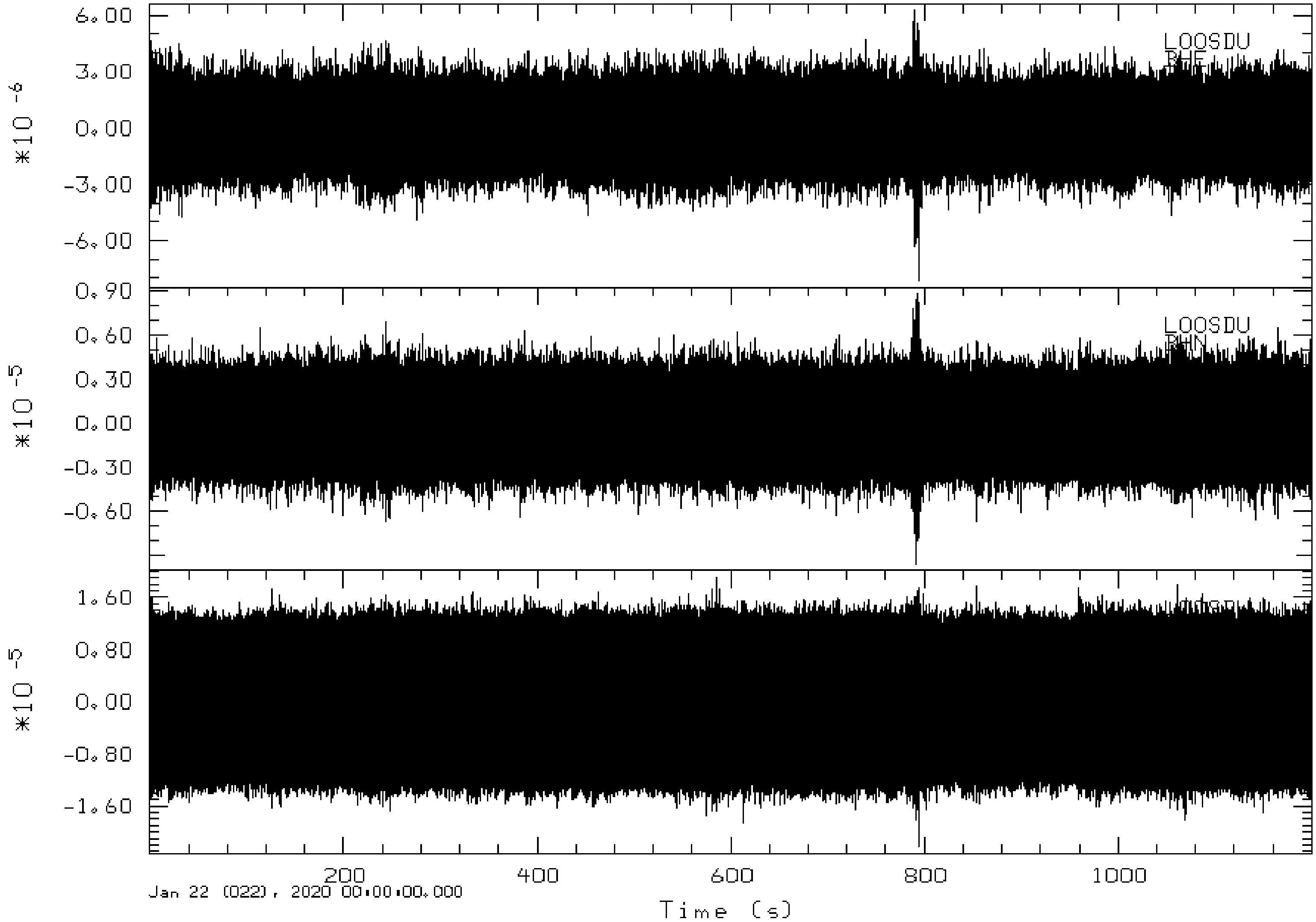
LOOSDU

LOOSDU - example of 20 minutes record during daily hours

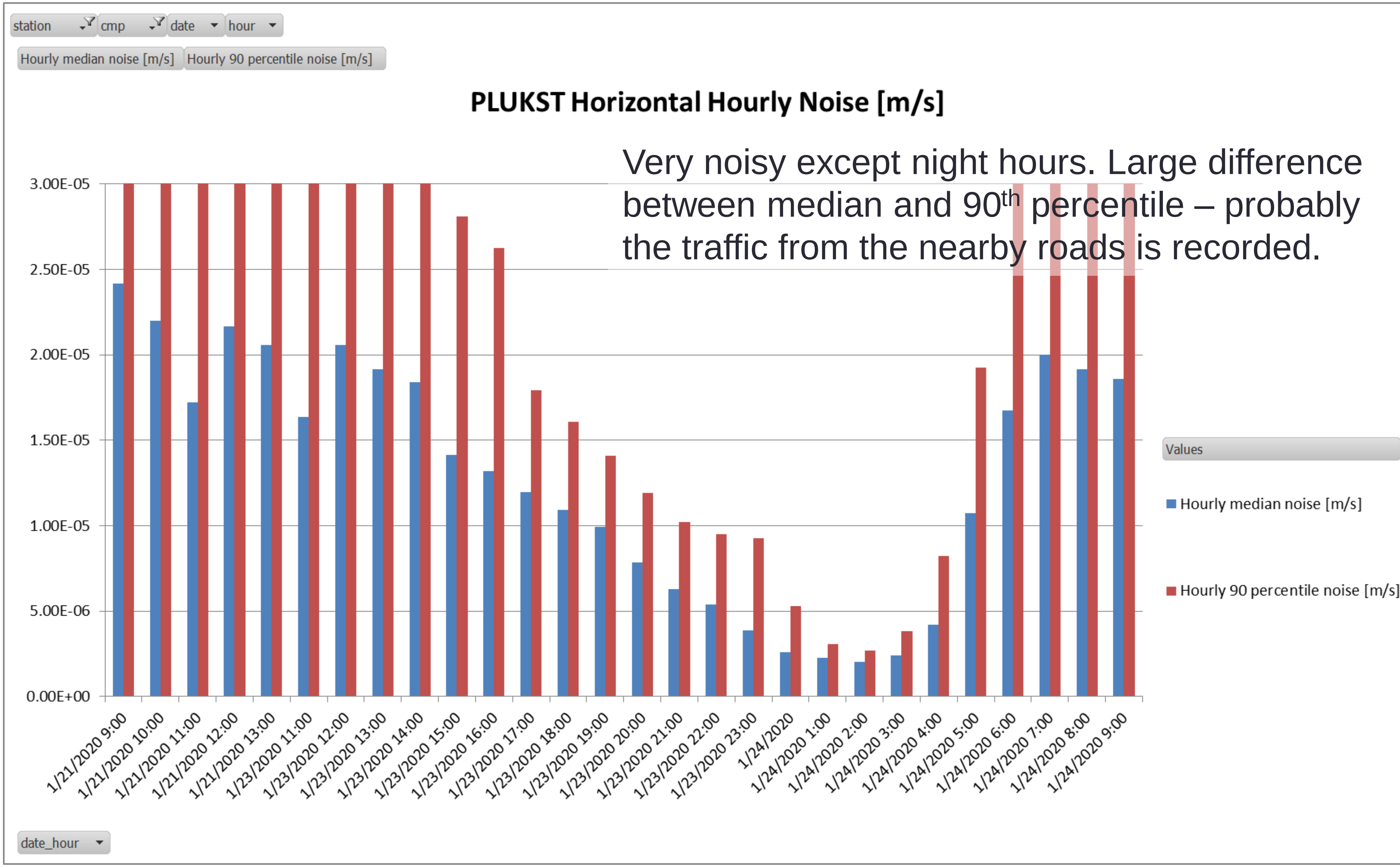


LOOSDU

LOOSDU - example of 20 minutes record during night hours

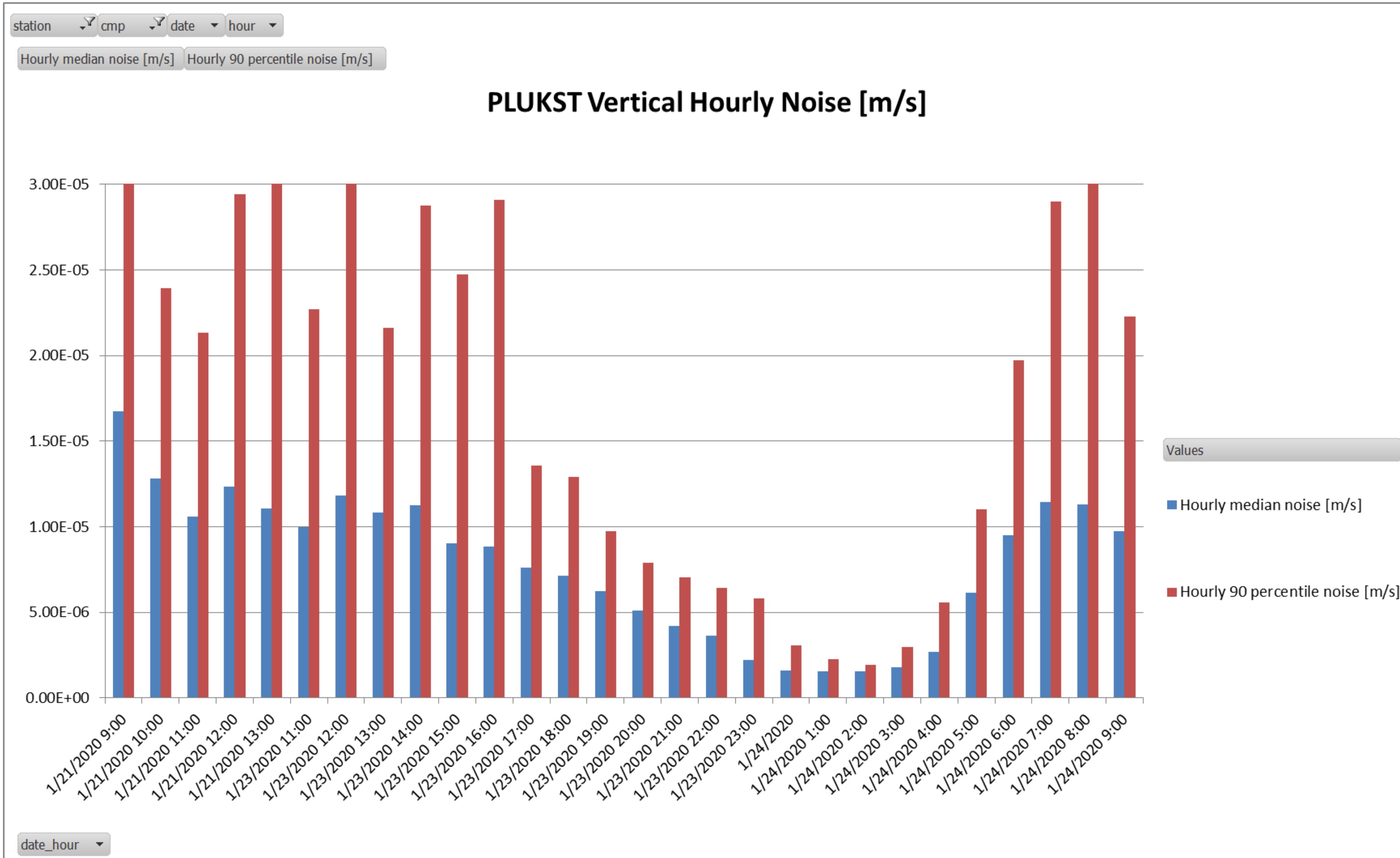


PLUKST



Very noisy except night hours. Large difference between median and 90th percentile – probably the traffic from the nearby roads is recorded.

PLUKST



station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
PLUKST Vertical Hourly Noise [m/s]
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/21/2020 9:00
1/21/2020 10:00
1/21/2020 11:00
1/21/2020 12:00
1/21/2020 13:00
1/23/2020 11:00
1/23/2020 12:00
1/23/2020 13:00
1/23/2020 14:00
1/23/2020 15:00
1/23/2020 16:00
1/23/2020 17:00
1/23/2020 18:00
1/23/2020 19:00
1/23/2020 20:00
1/23/2020 21:00
1/23/2020 22:00
1/23/2020 23:00
1/24/2020
1/24/2020 1:00
1/24/2020 2:00
1/24/2020 3:00
1/24/2020 4:00
1/24/2020 5:00
1/24/2020 6:00
1/24/2020 7:00
1/24/2020 8:00
1/24/2020 9:00
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

PLUKST

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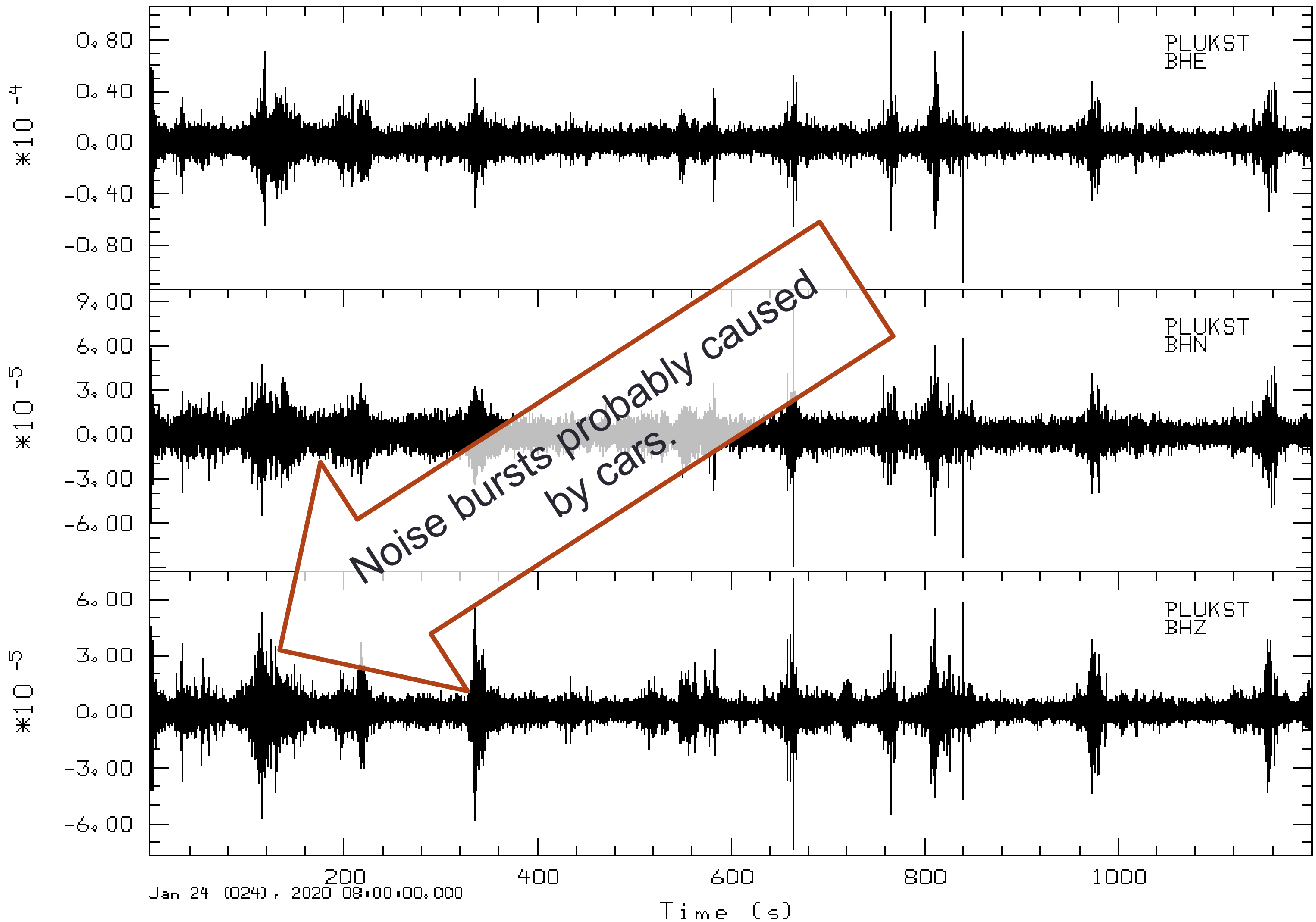
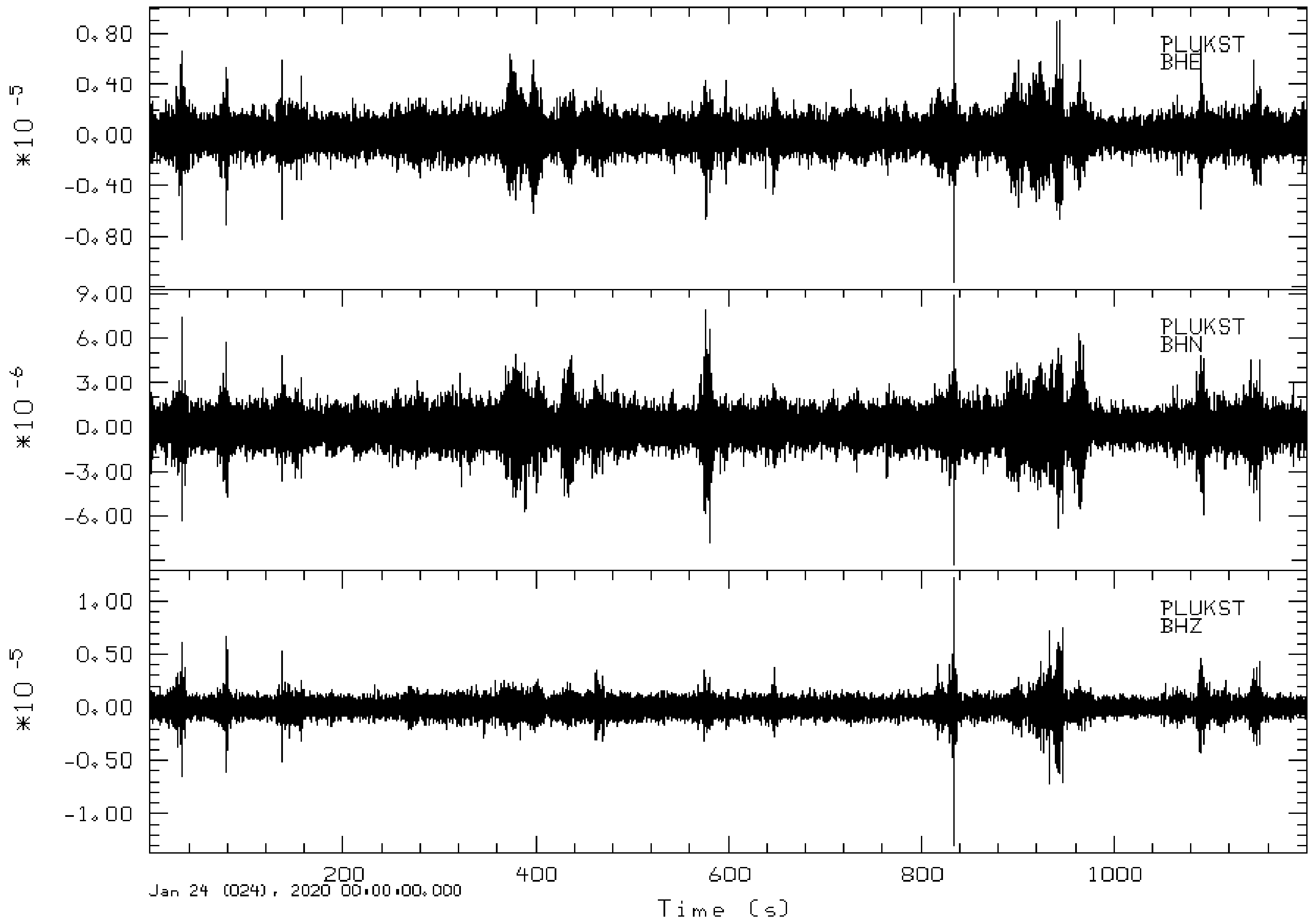
PLUKST - example of 20 minutes record during daily hours

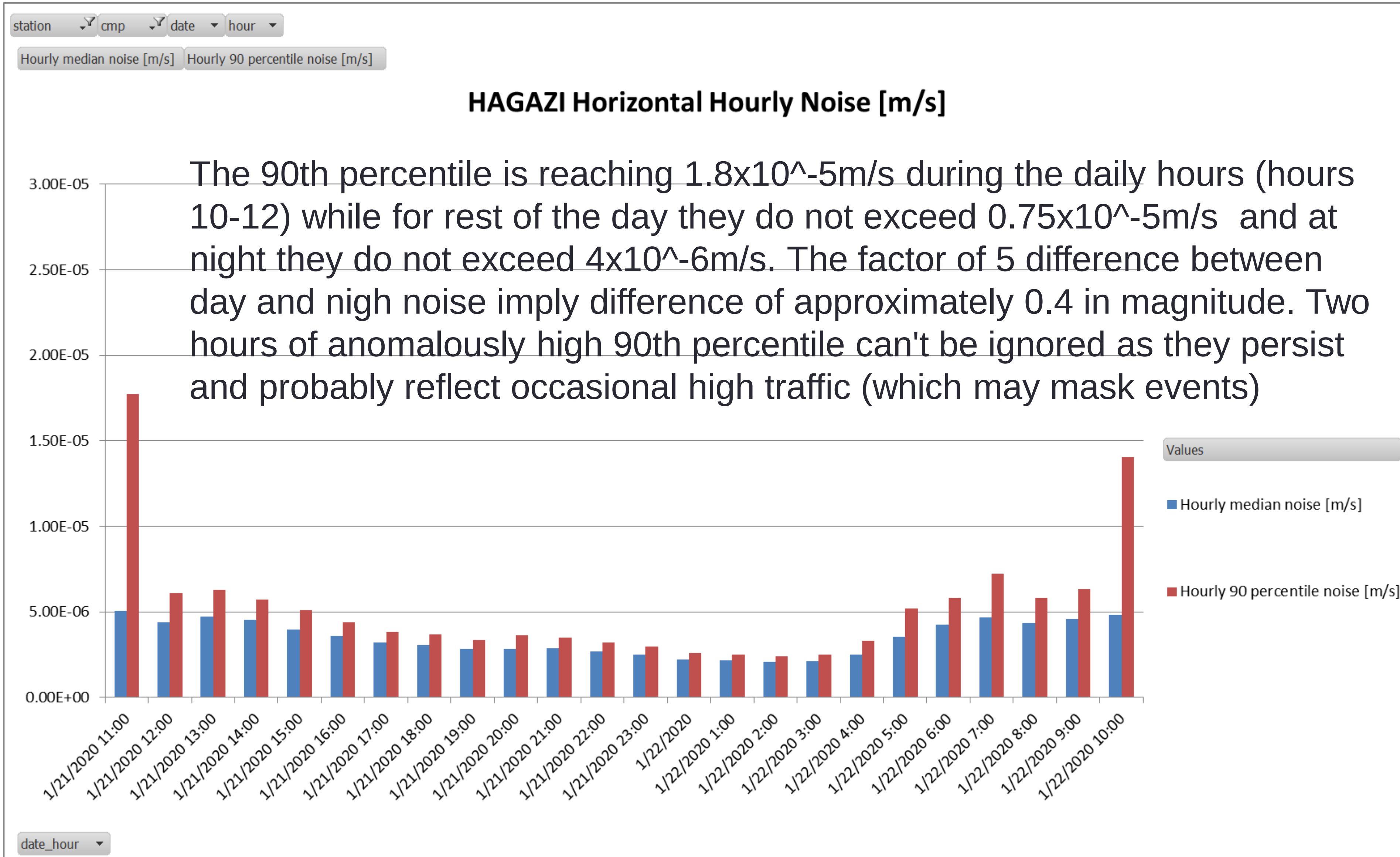


PLUKST

PLUKST - example of 20 minutes record during night hours

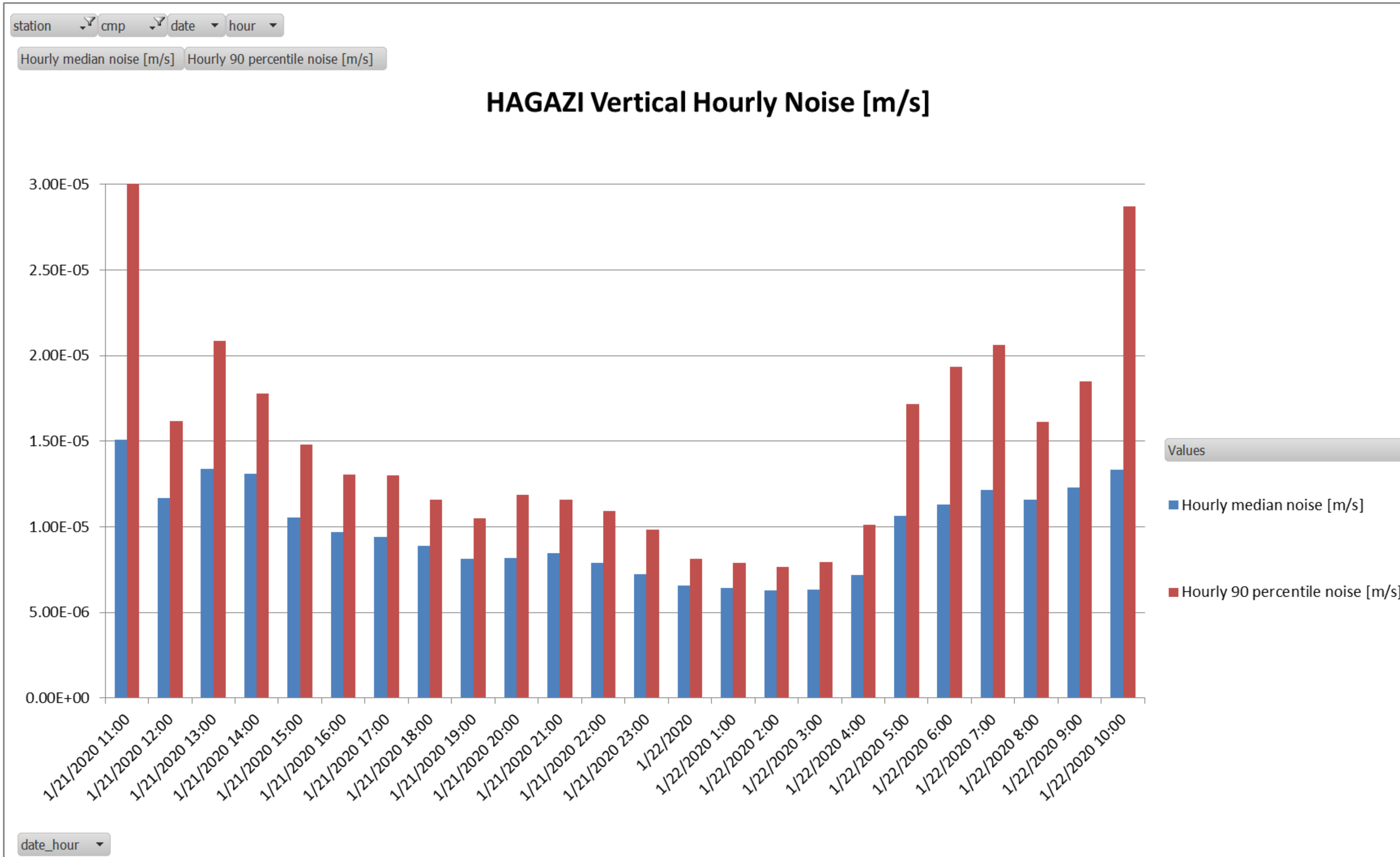


HAGAZI



The 90th percentile is reaching 1.8x10^-5m/s during the daily hours (hours 10-12) while for rest of the day they do not exceed 0.75x10^-5m/s and at night they do not exceed 4x10^-6m/s. The factor of 5 difference between day and nigh noise imply difference of approximately 0.4 in magnitude. Two hours of anomalously high 90th percentile can't be ignored as they persist and probably reflect occasional high traffic (which may mask events)

HAGAZI



station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
HAGAZI Vertical Hourly Noise [m/s]
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/21/2020 11:00
1/21/2020 12:00
1/21/2020 13:00
1/21/2020 14:00
1/21/2020 15:00
1/21/2020 16:00
1/21/2020 17:00
1/21/2020 18:00
1/21/2020 19:00
1/21/2020 20:00
1/21/2020 21:00
1/21/2020 22:00
1/21/2020 23:00
1/22/2020
1/22/2020 1:00
1/22/2020 2:00
1/22/2020 3:00
1/22/2020 4:00
1/22/2020 5:00
1/22/2020 6:00
1/22/2020 7:00
1/22/2020 8:00
1/22/2020 9:00
1/22/2020 10:00
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

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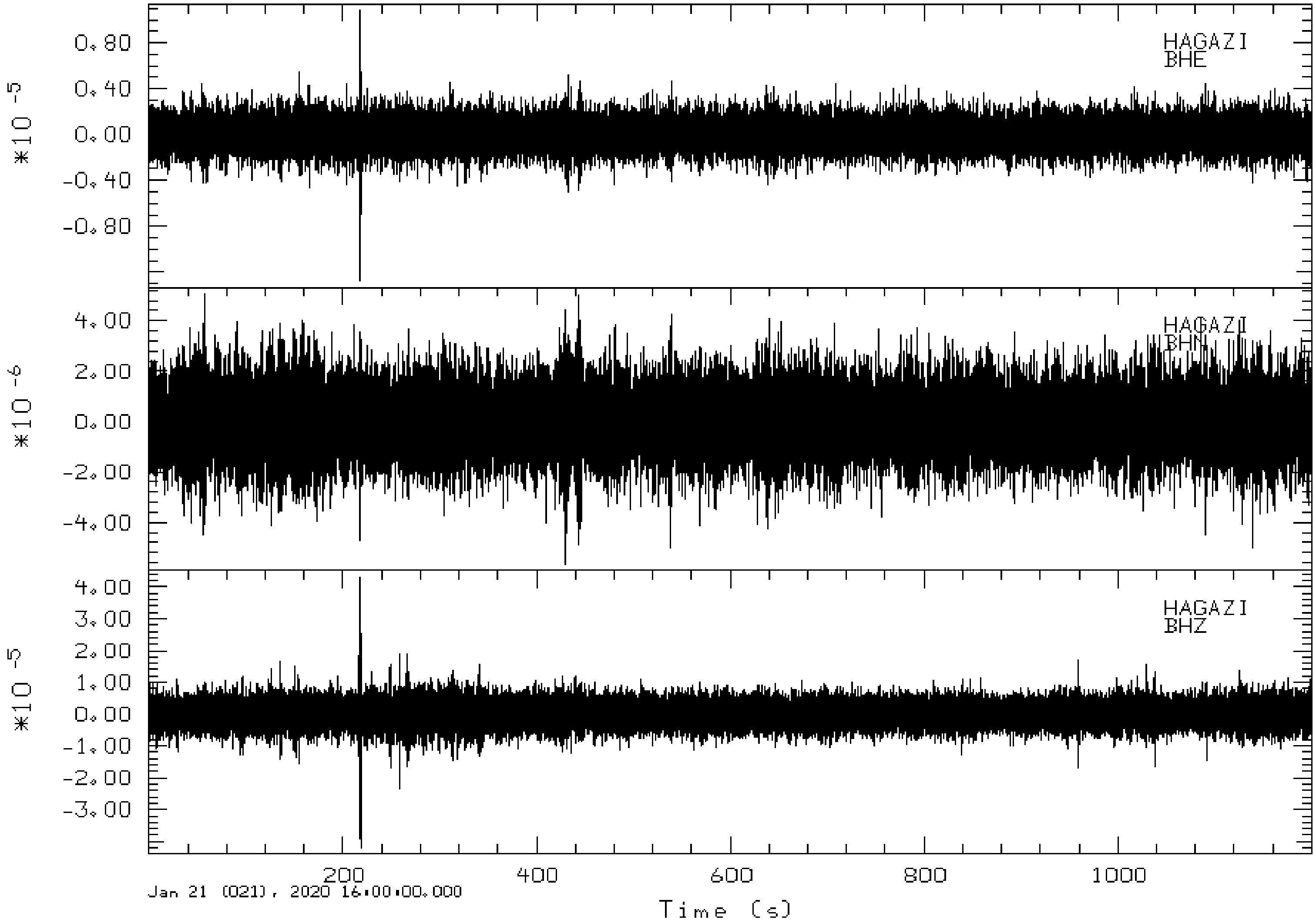
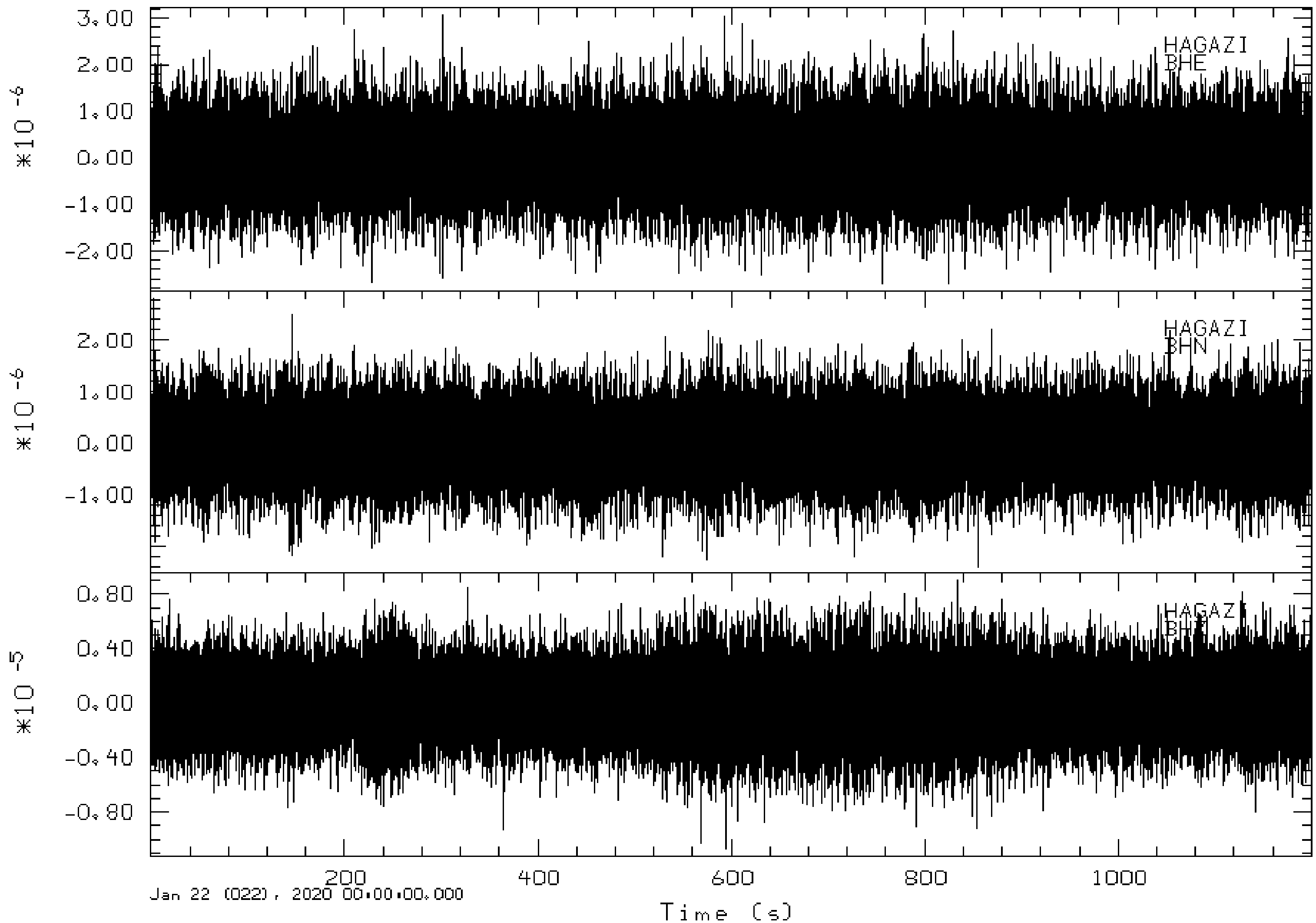
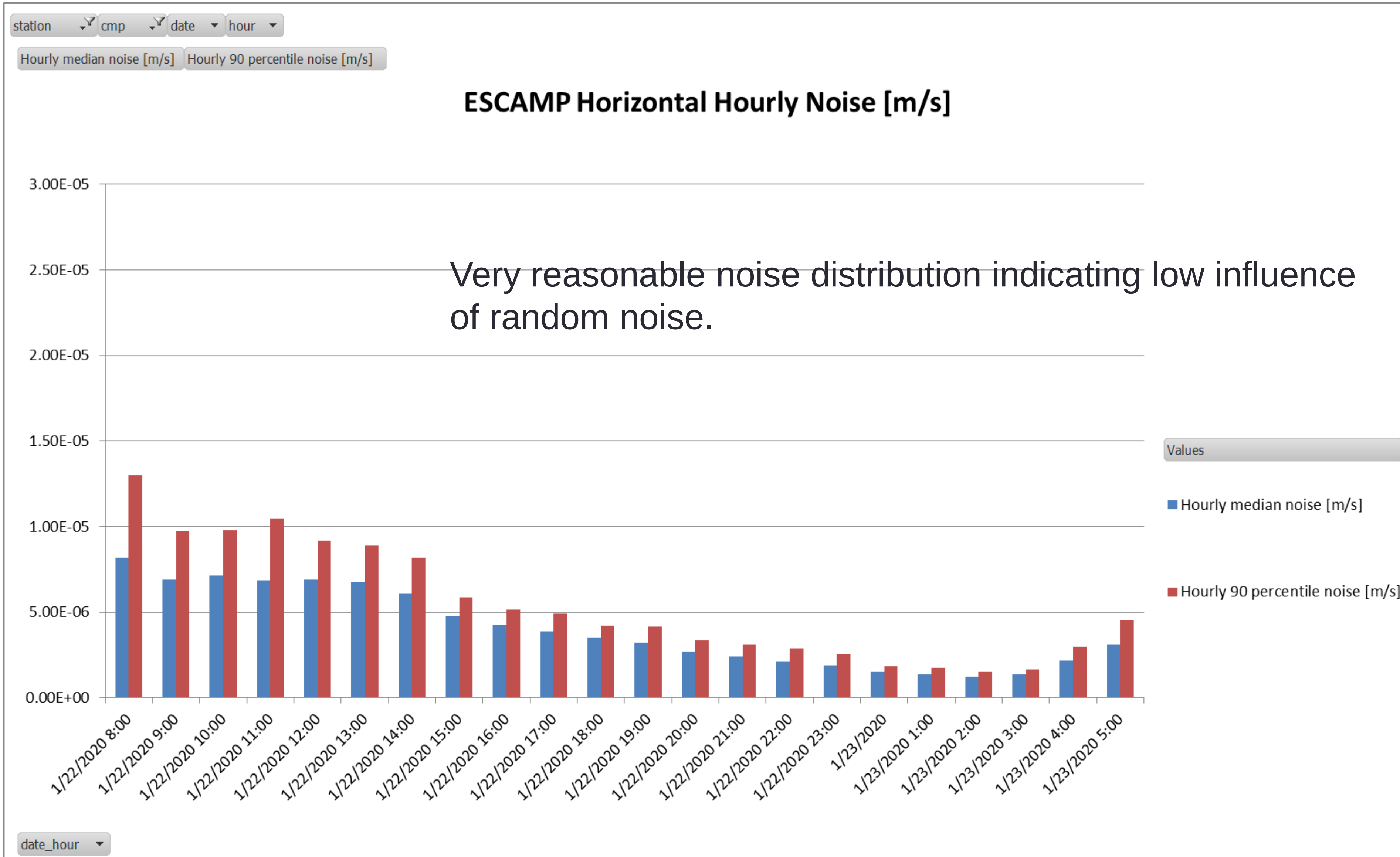
HAGAZI - example of 20 minutes record during daily hours



HAGAZI - example of 20 minutes record during night hours

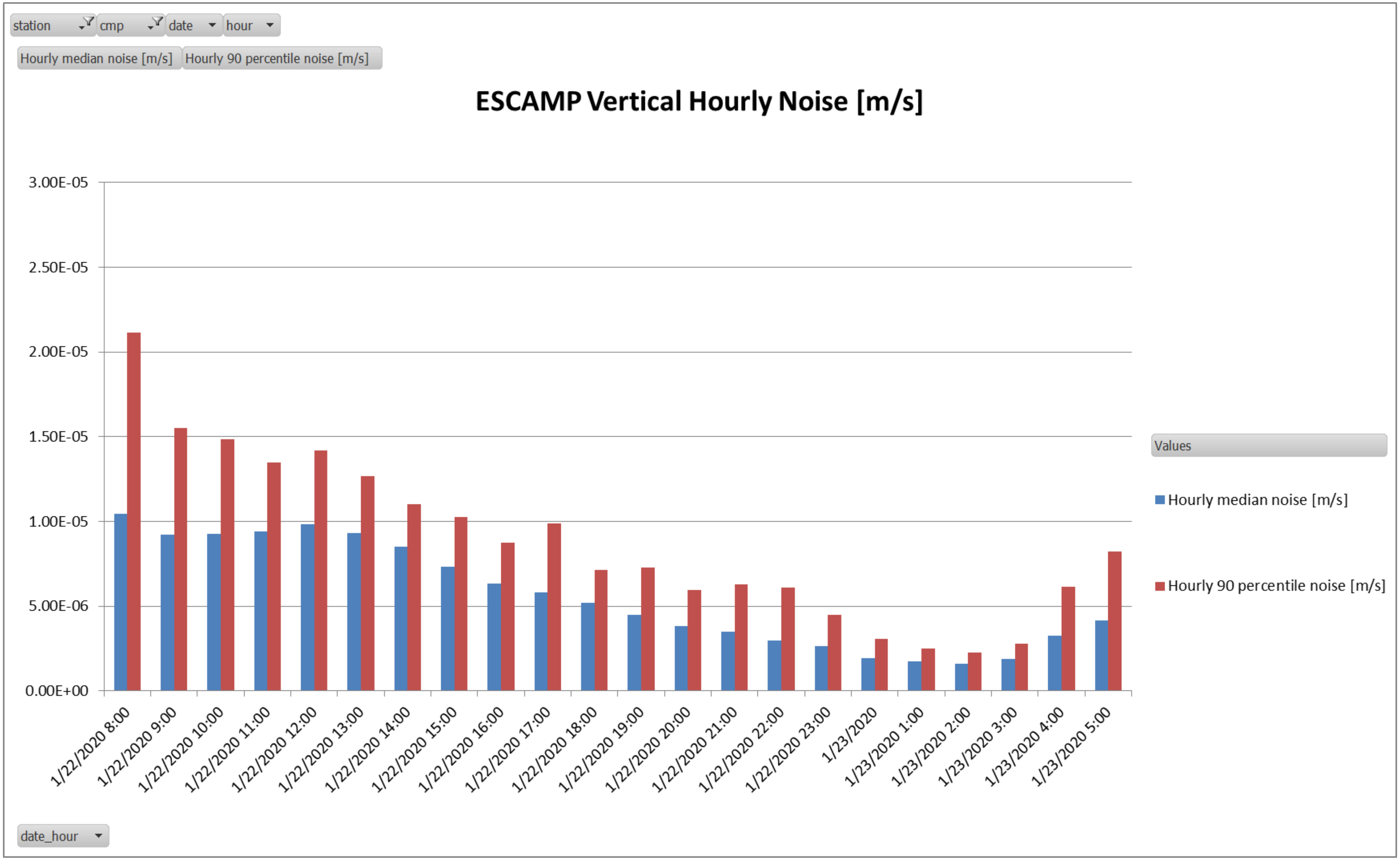


ESCAMP



Very reasonable noise distribution indicating low influence of random noise.

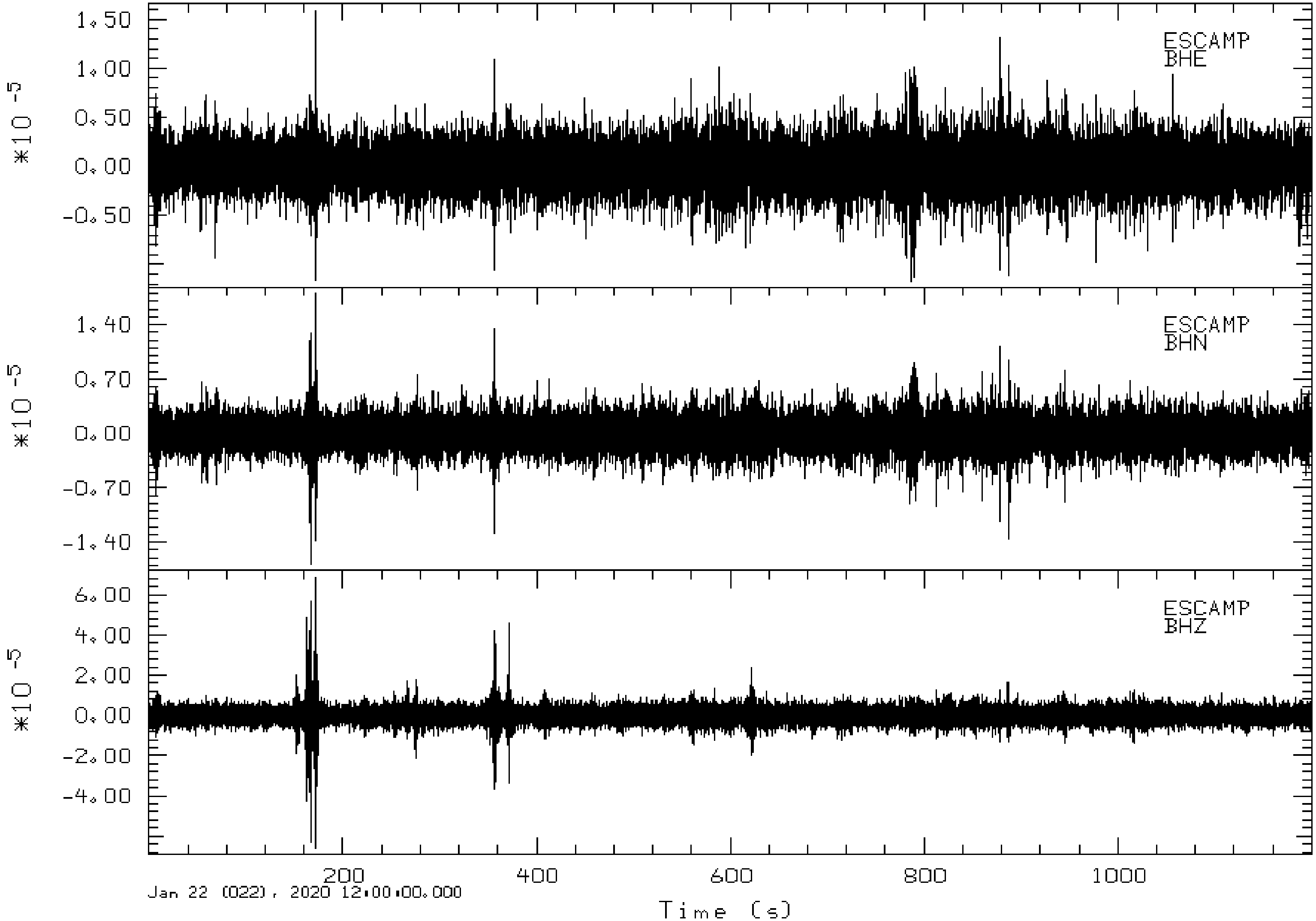
ESCAMP



station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
ESCAMP Vertical Hourly Noise [m/s]
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/22/2020 8:00
1/22/2020 9:00
1/22/2020 10:00
1/22/2020 11:00
1/22/2020 12:00
1/22/2020 13:00
1/22/2020 14:00
1/22/2020 15:00
1/22/2020 16:00
1/22/2020 17:00
1/22/2020 18:00
1/22/2020 19:00
1/22/2020 20:00
1/22/2020 21:00
1/22/2020 22:00
1/22/2020 23:00
1/23/2020
1/23/2020 1:00
1/23/2020 2:00
1/23/2020 3:00
1/23/2020 4:00
1/23/2020 5:00
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

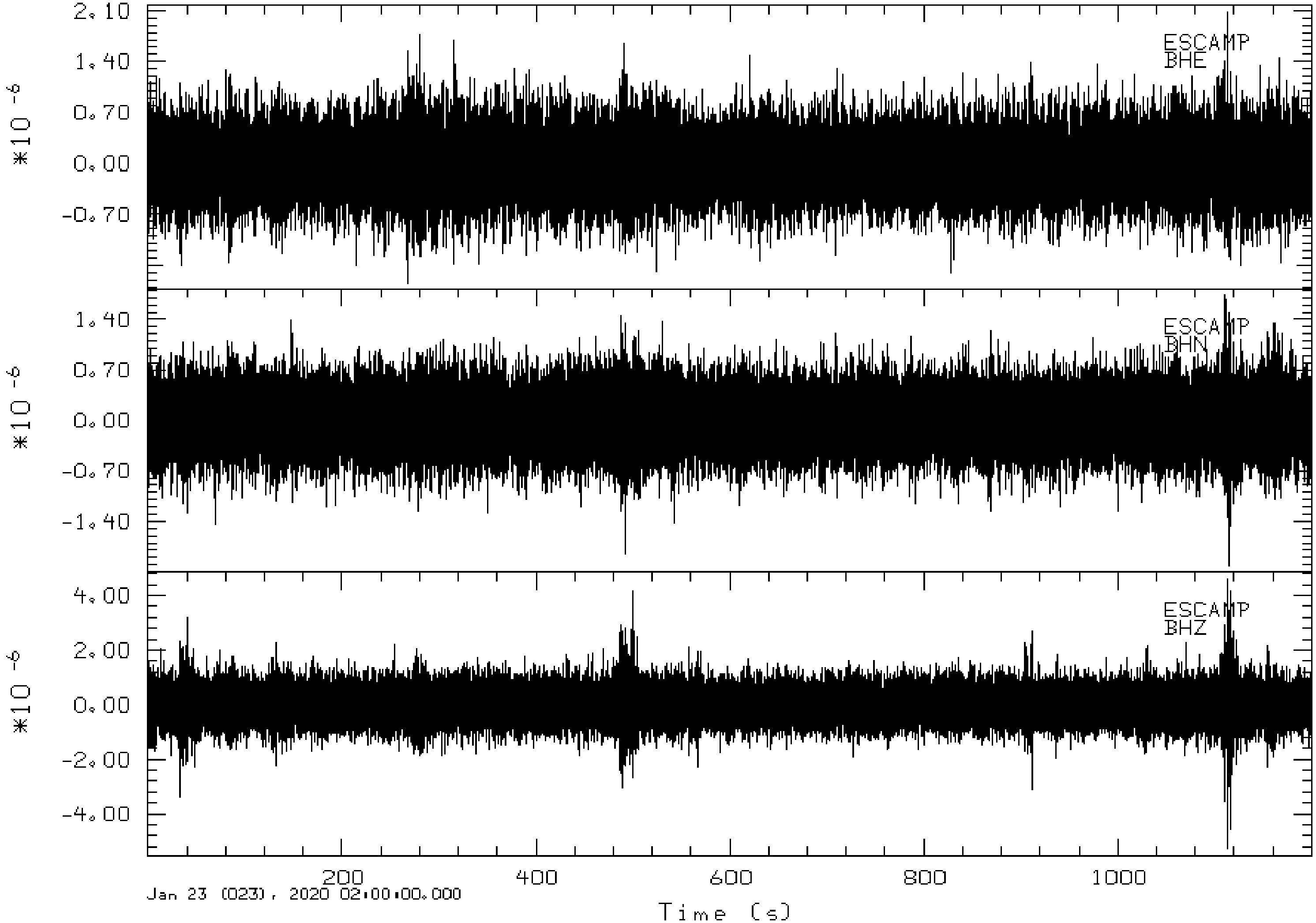
ESCAMP

ESCAMP - example of 20 minutes record during daily hours



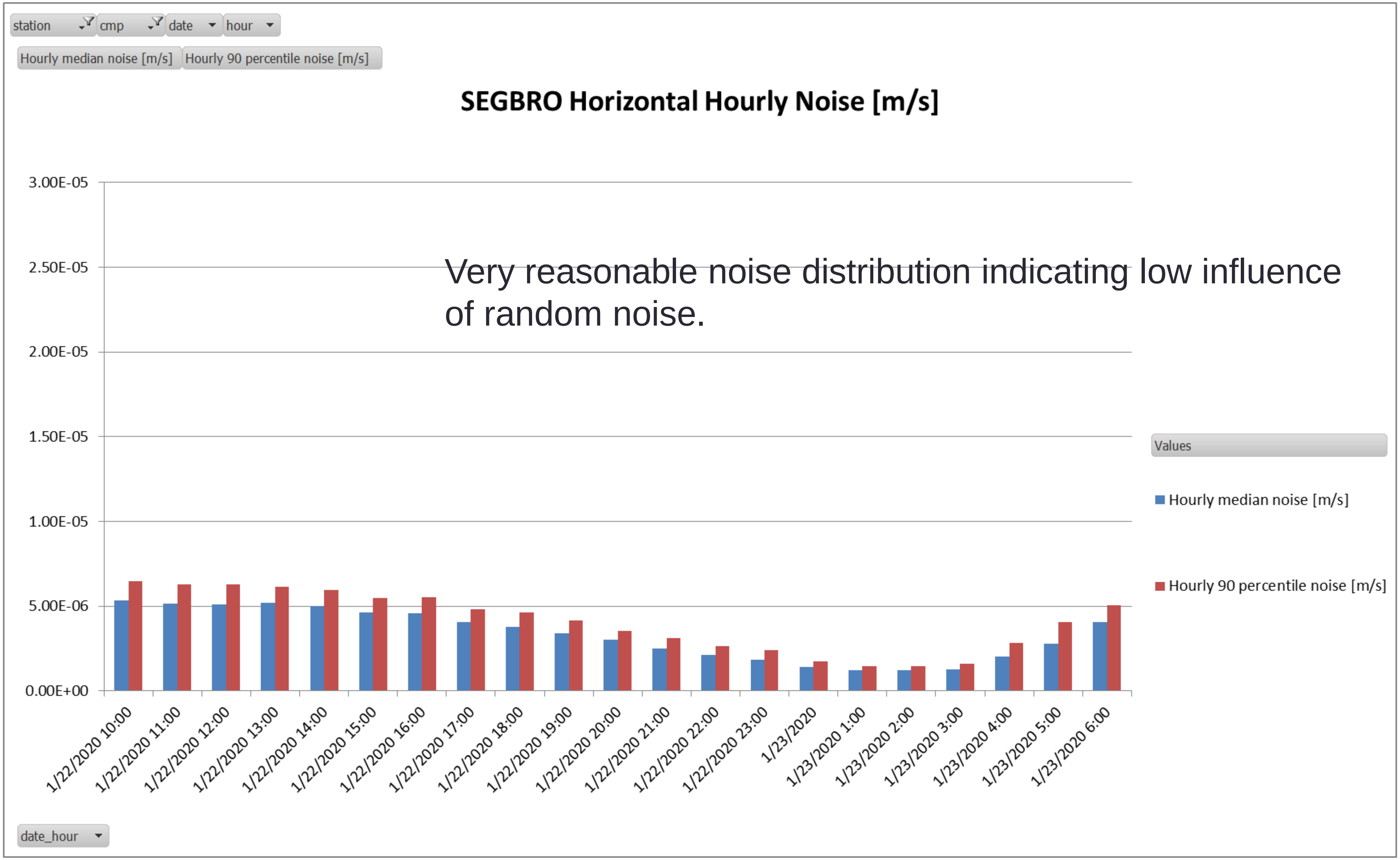
ESCAMP

ESCAMP - example of 20 minutes record during night hours

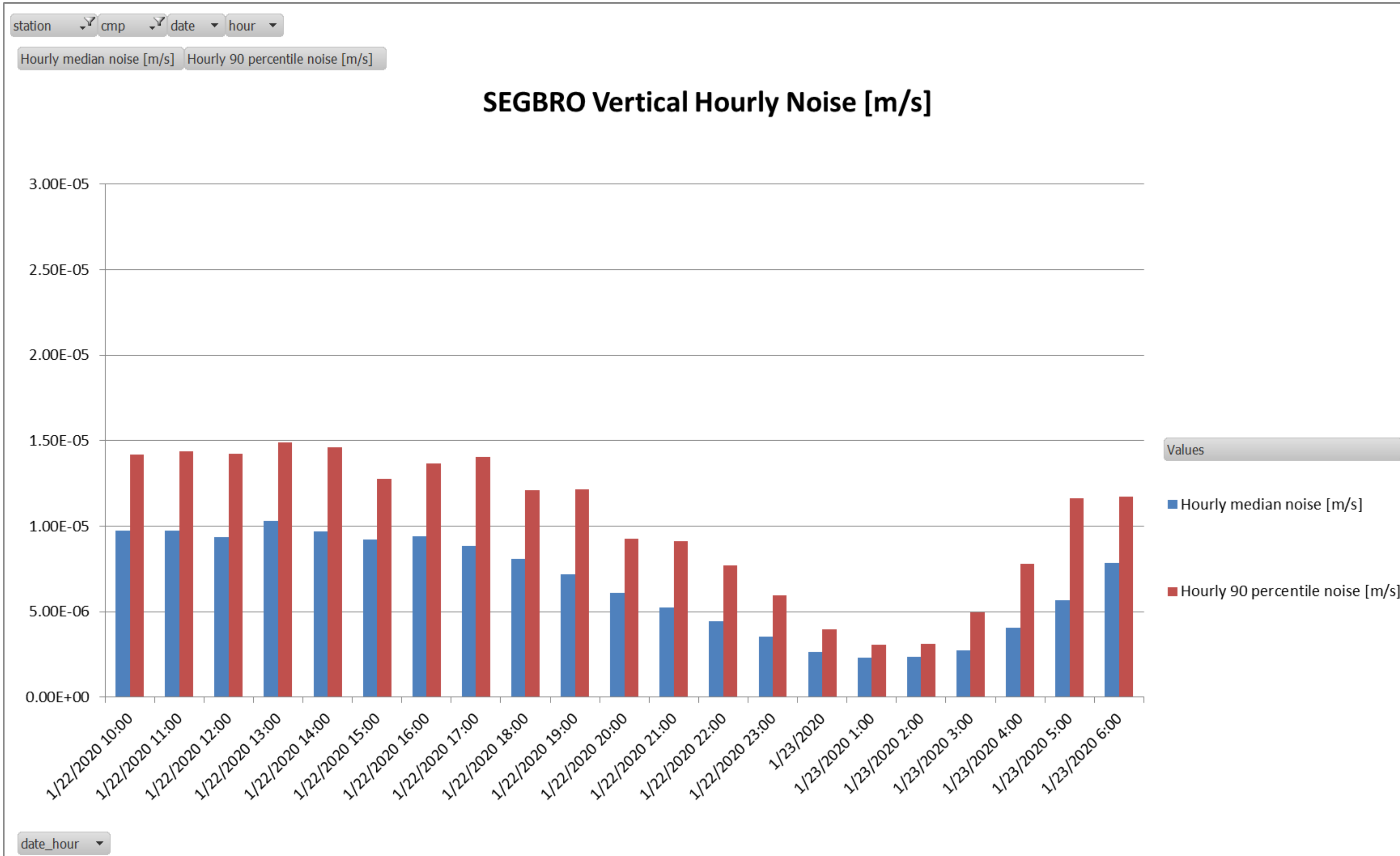


SEGBRO

Very reasonable noise distribution indicating low influence of random noise.

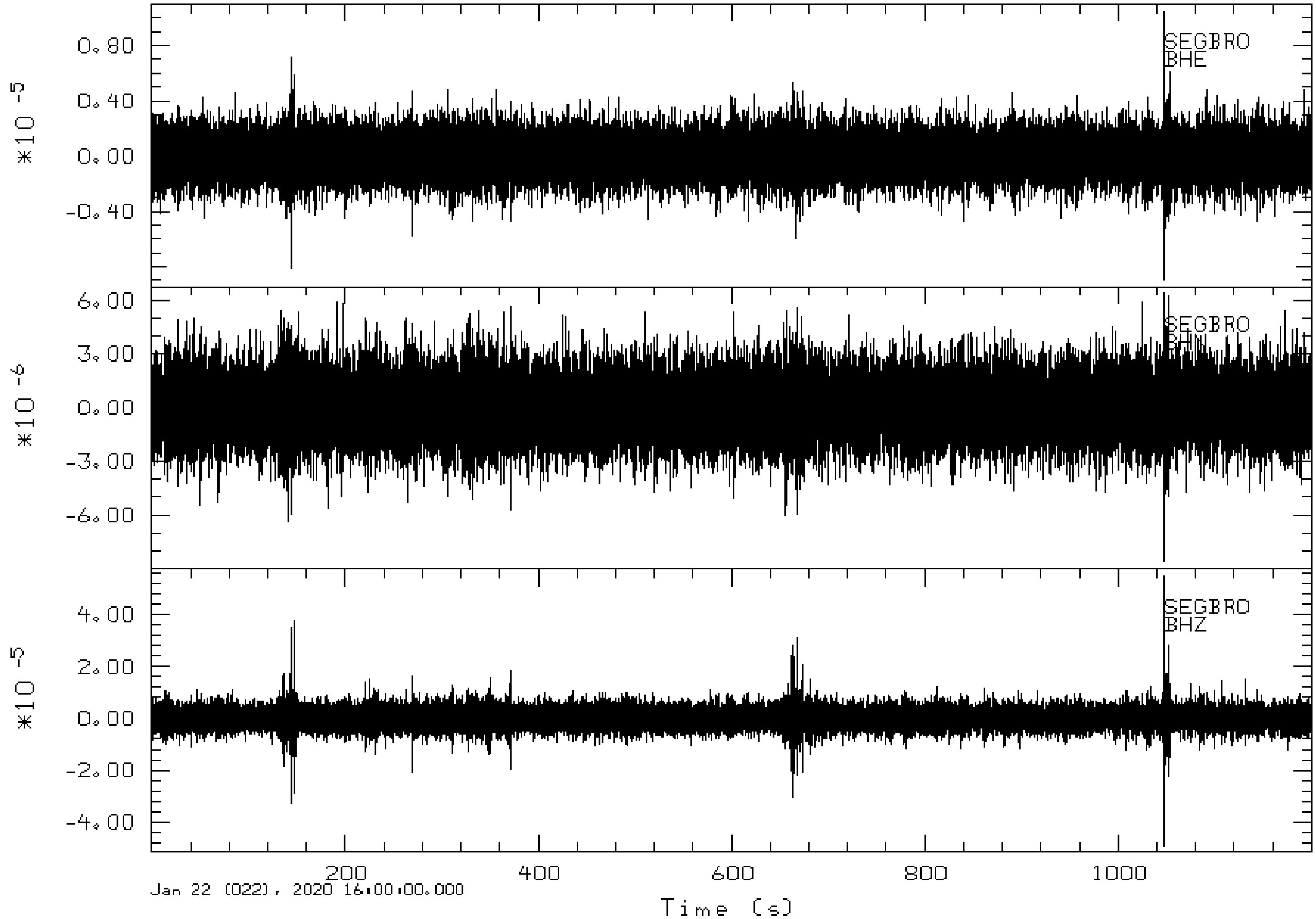


SEGBRO


station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
SEGBRO Vertical Hourly Noise [m/s]
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/22/2020 10:00
1/22/2020 11:00
1/22/2020 12:00
1/22/2020 13:00
1/22/2020 14:00
1/22/2020 15:00
1/22/2020 16:00
1/22/2020 17:00
1/22/2020 18:00
1/22/2020 19:00
1/22/2020 20:00
1/22/2020 21:00
1/22/2020 22:00
1/22/2020 23:00
1/23/2020
1/23/2020 1:00
1/23/2020 2:00
1/23/2020 3:00
1/23/2020 4:00
1/23/2020 5:00
1/23/2020 6:00
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

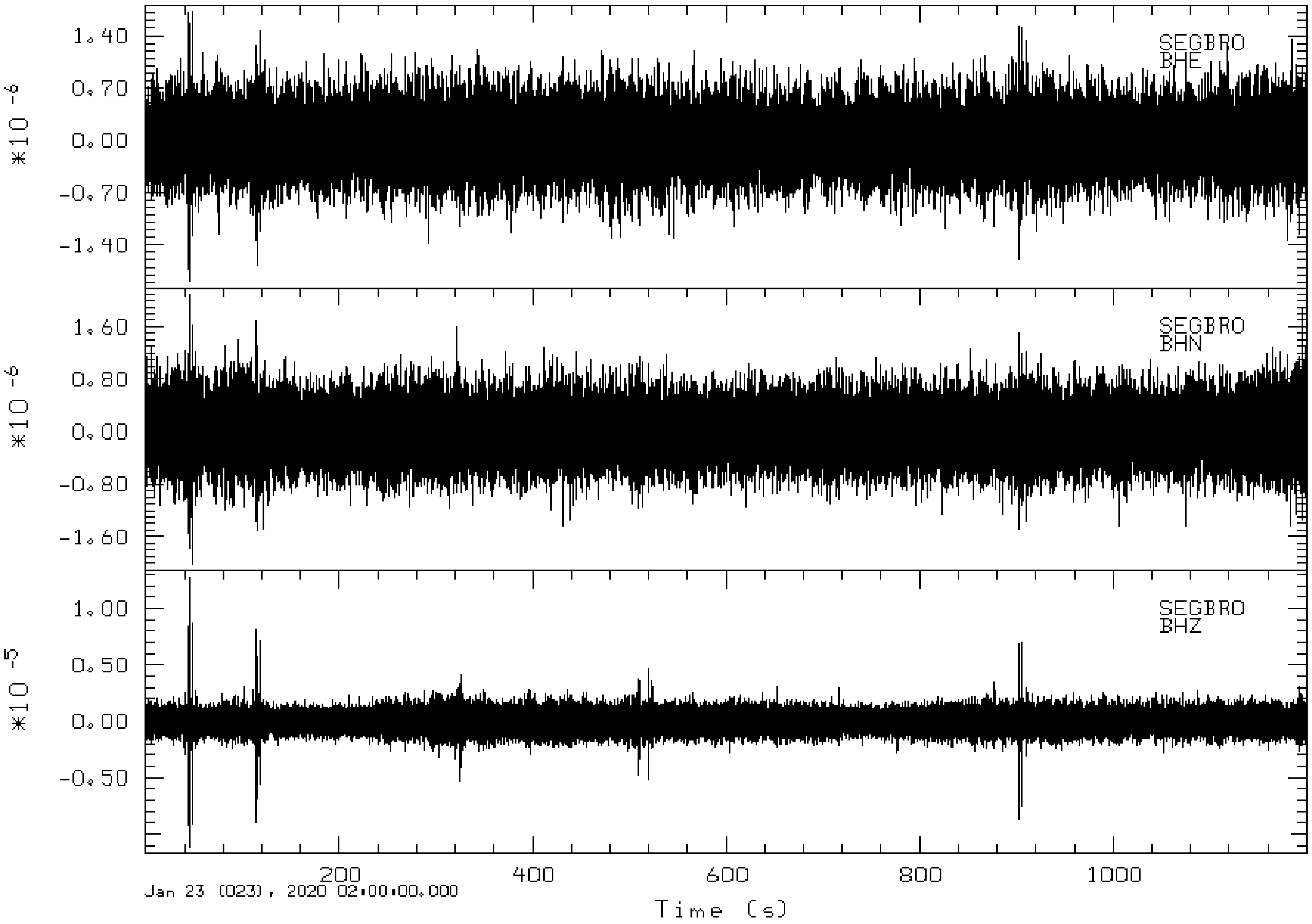
SEGBRO

SEGBRO - example of 20 minutes record during daily hours

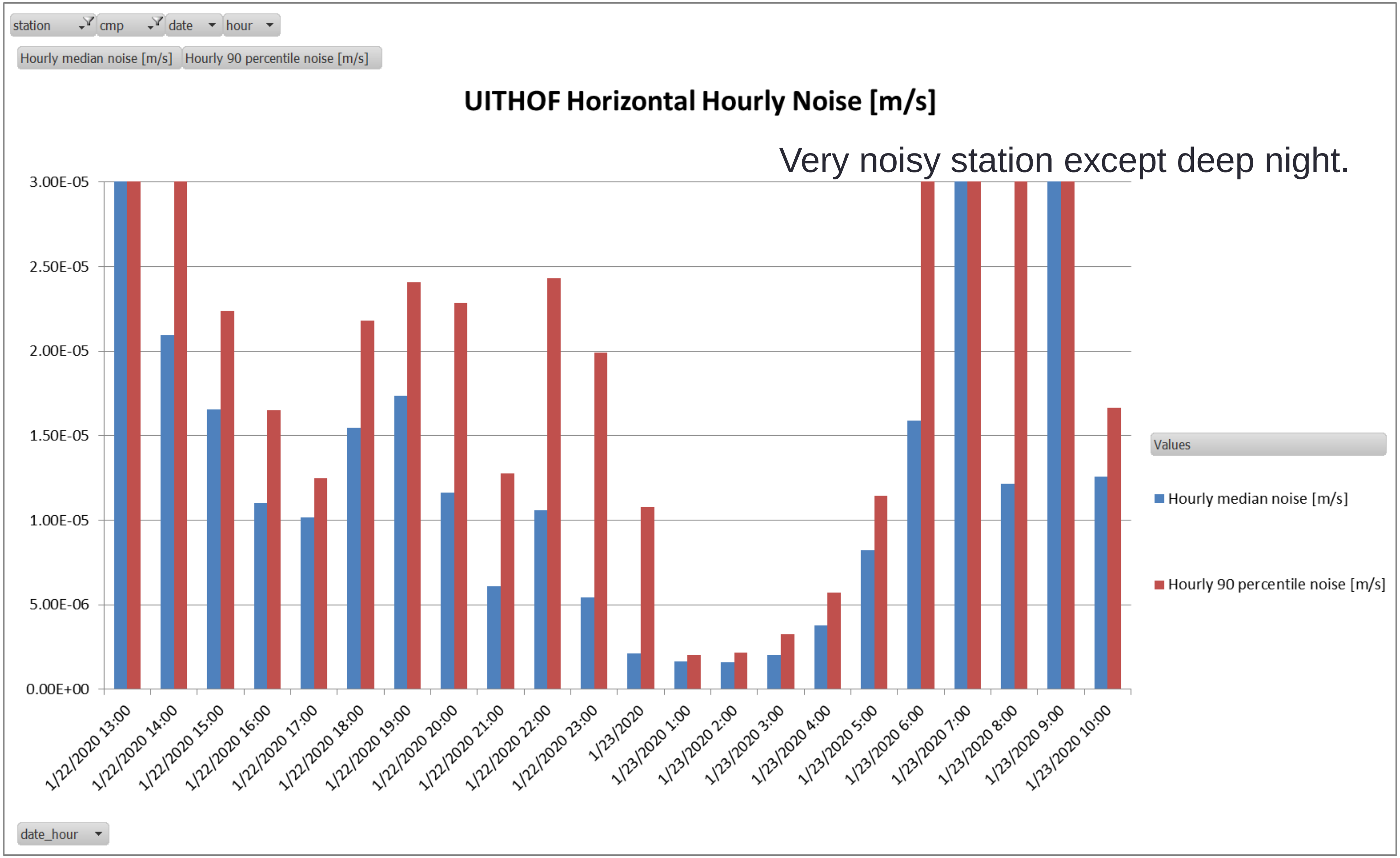


SEGBRO

SEGBRO - example of 20 minutes record during night hours

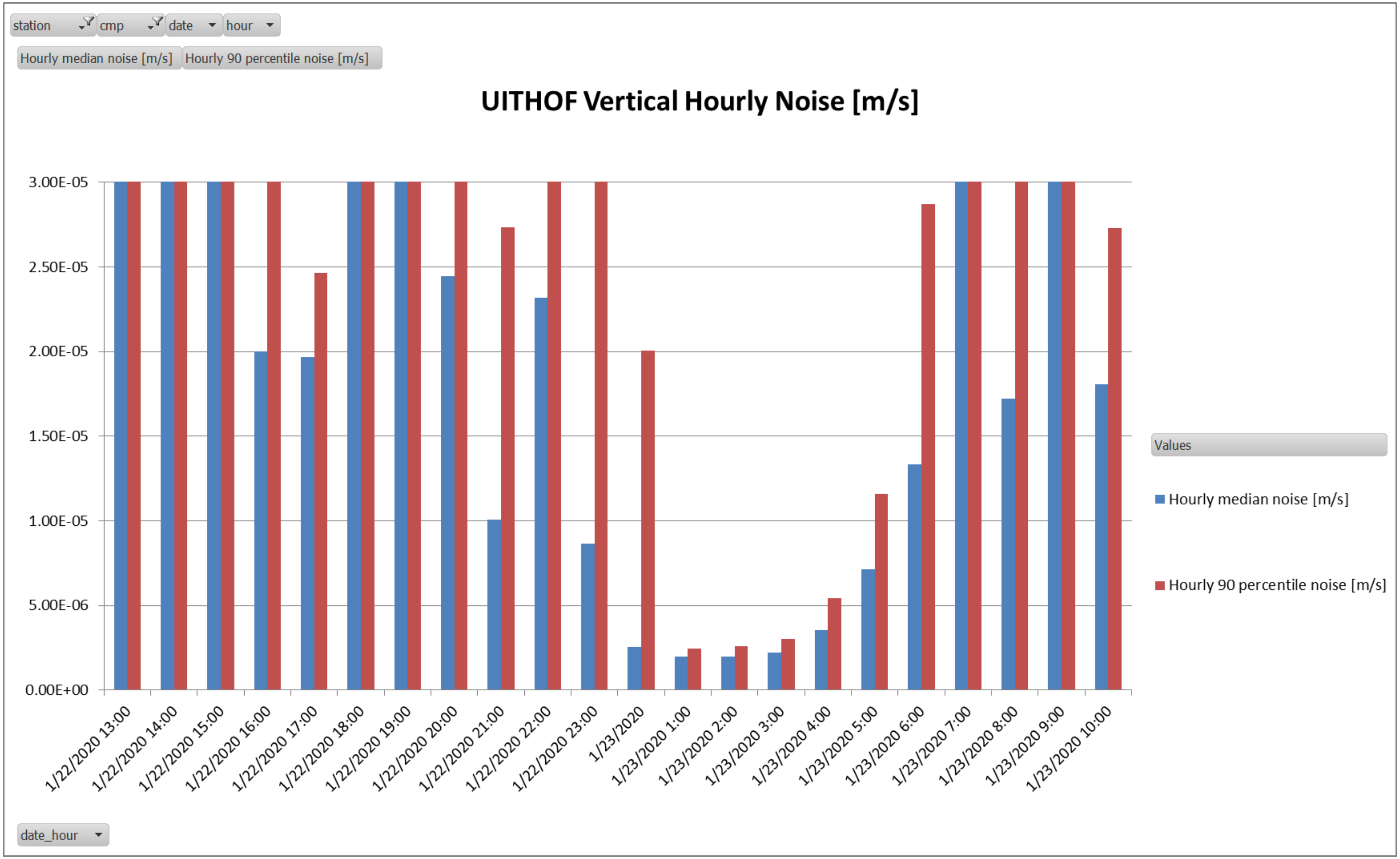


UITHOF



Very noisy station except deep night.

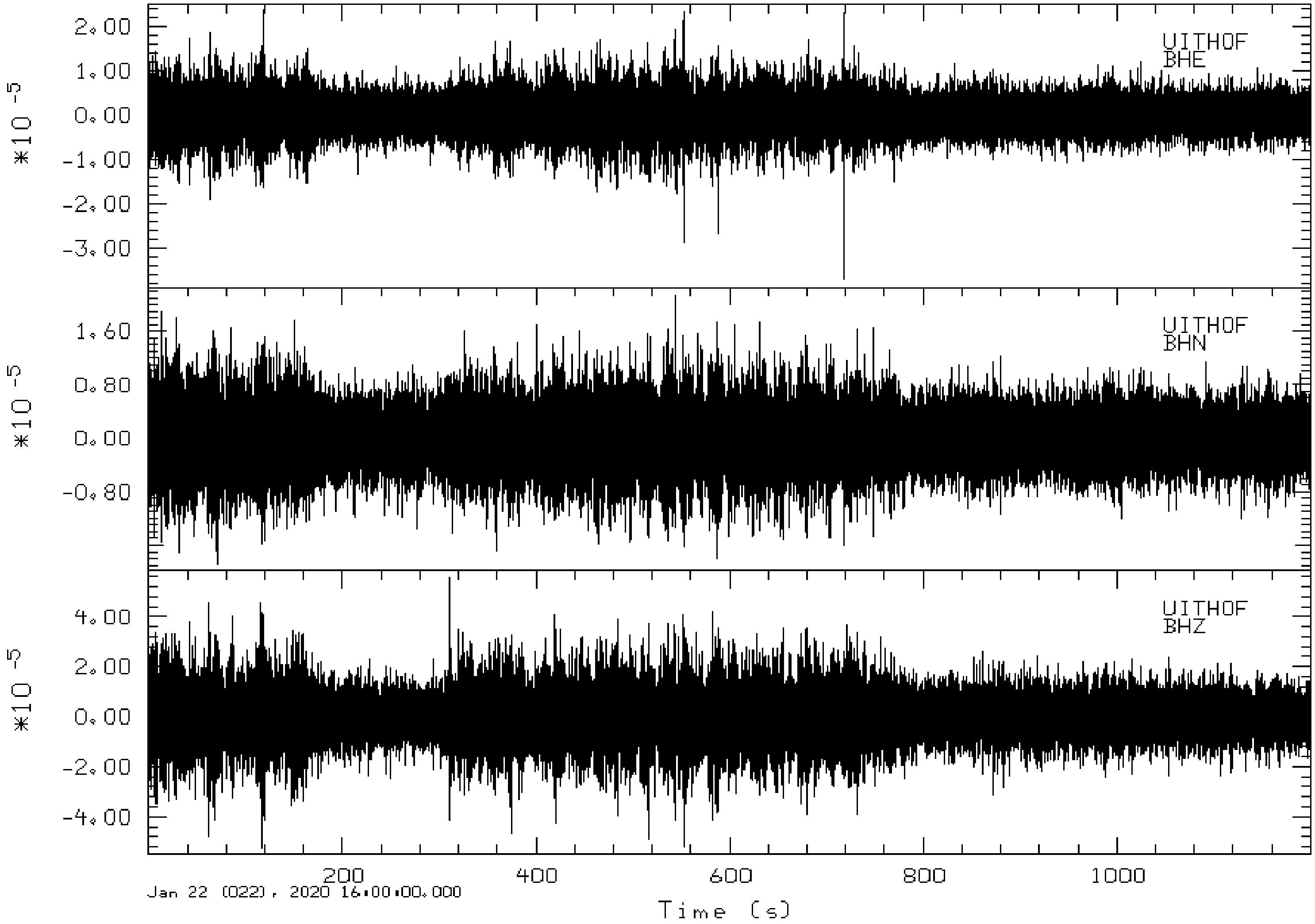
UITHOF



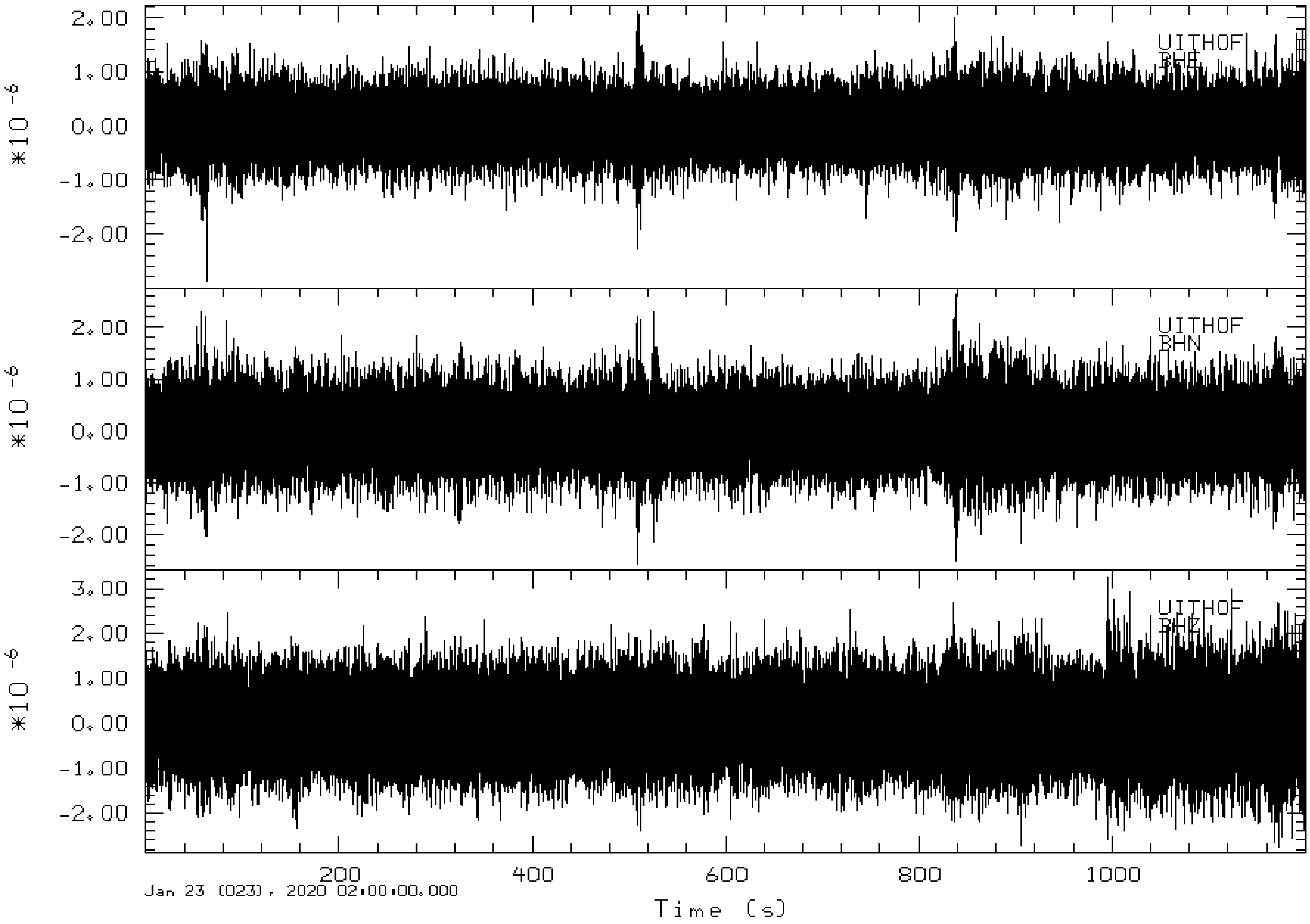
station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
UITHOF Vertical Hourly Noise [m/s]
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/22/2020 13:00
1/22/2020 14:00
1/22/2020 15:00
1/22/2020 16:00
1/22/2020 17:00
1/22/2020 18:00
1/22/2020 19:00
1/22/2020 20:00
1/22/2020 21:00
1/22/2020 22:00
1/22/2020 23:00
1/23/2020
1/23/2020 1:00
1/23/2020 2:00
1/23/2020 3:00
1/23/2020 4:00
1/23/2020 5:00
1/23/2020 6:00
1/23/2020 7:00
1/23/2020 8:00
1/23/2020 9:00
1/23/2020 10:00
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

UITHOF

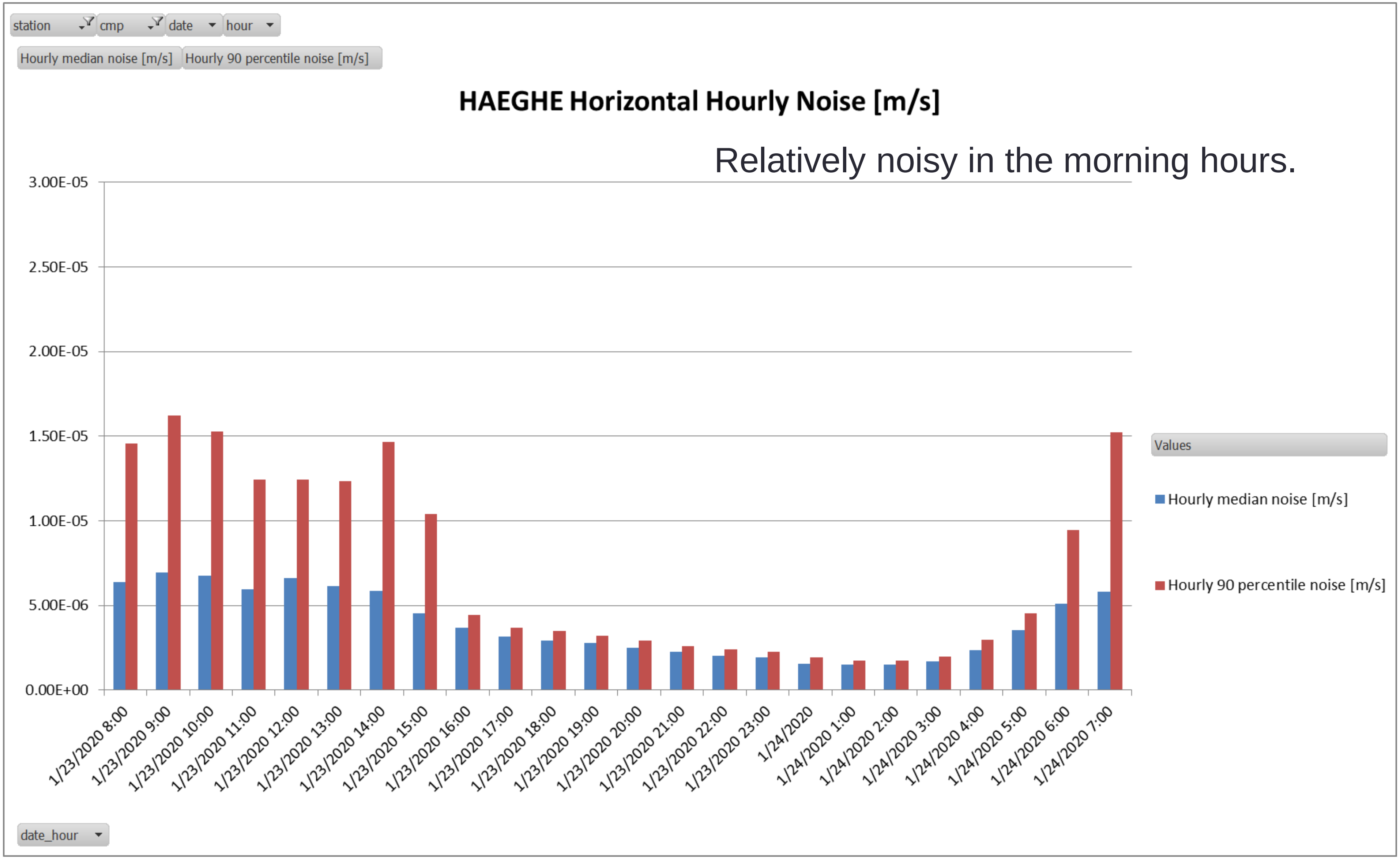
UITHOF - example of 20 minutes record during daily hours



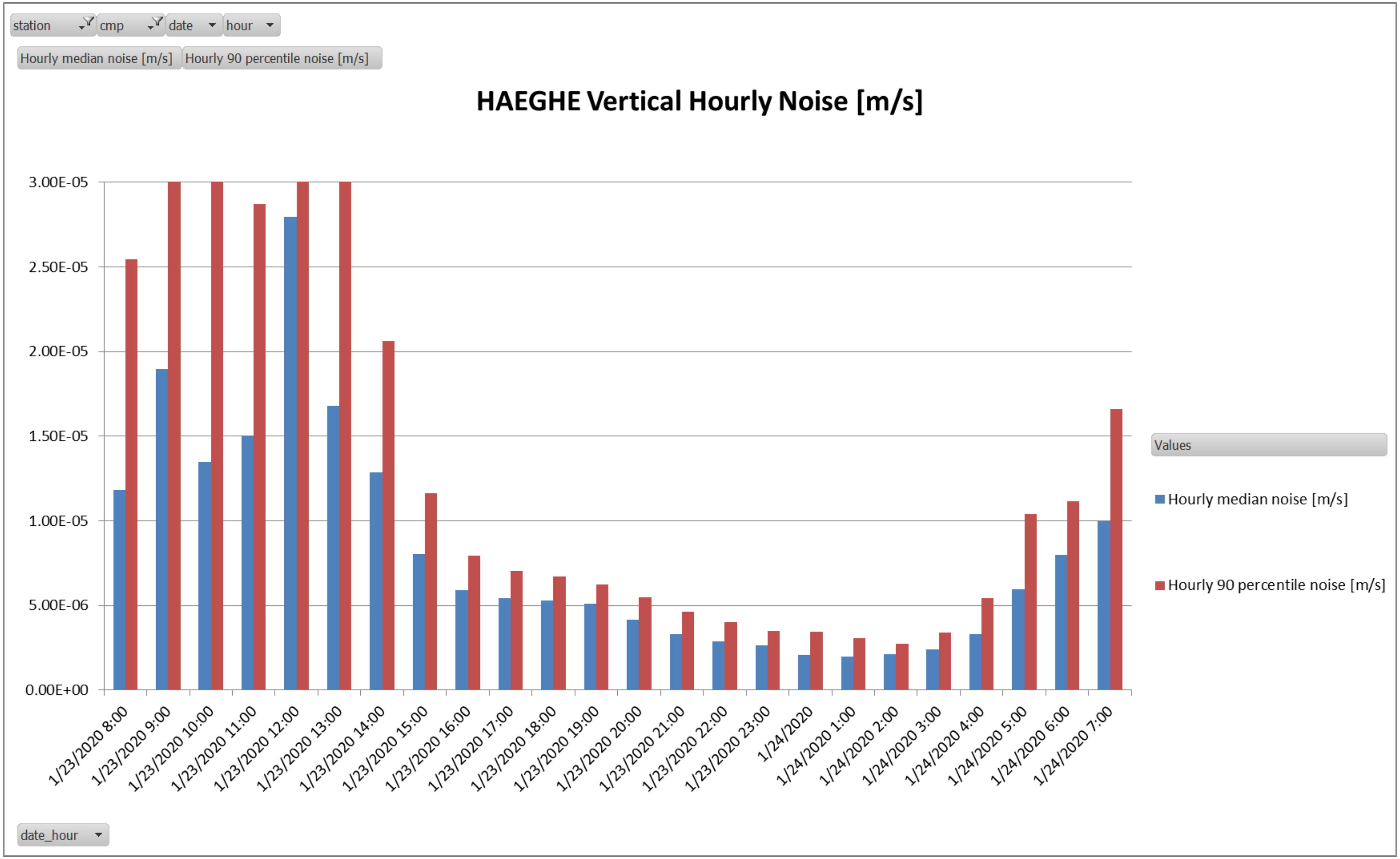
UITHOF - example of 20 minutes record during night hours



HAEGHE


station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
HAEGHE Horizontal Hourly Noise [m/s]
Relatively noisy in the morning hours.
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/23/2020 8:00
1/23/2020 9:00
1/23/2020 10:00
1/23/2020 11:00
1/23/2020 12:00
1/23/2020 13:00
1/23/2020 14:00
1/23/2020 15:00
1/23/2020 16:00
1/23/2020 17:00
1/23/2020 18:00
1/23/2020 19:00
1/23/2020 20:00
1/23/2020 21:00
1/23/2020 22:00
1/23/2020 23:00
1/24/2020
1/24/2020 1:00
1/24/2020 2:00
1/24/2020 3:00
1/24/2020 4:00
1/24/2020 5:00
1/24/2020 6:00
1/24/2020 7:00
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

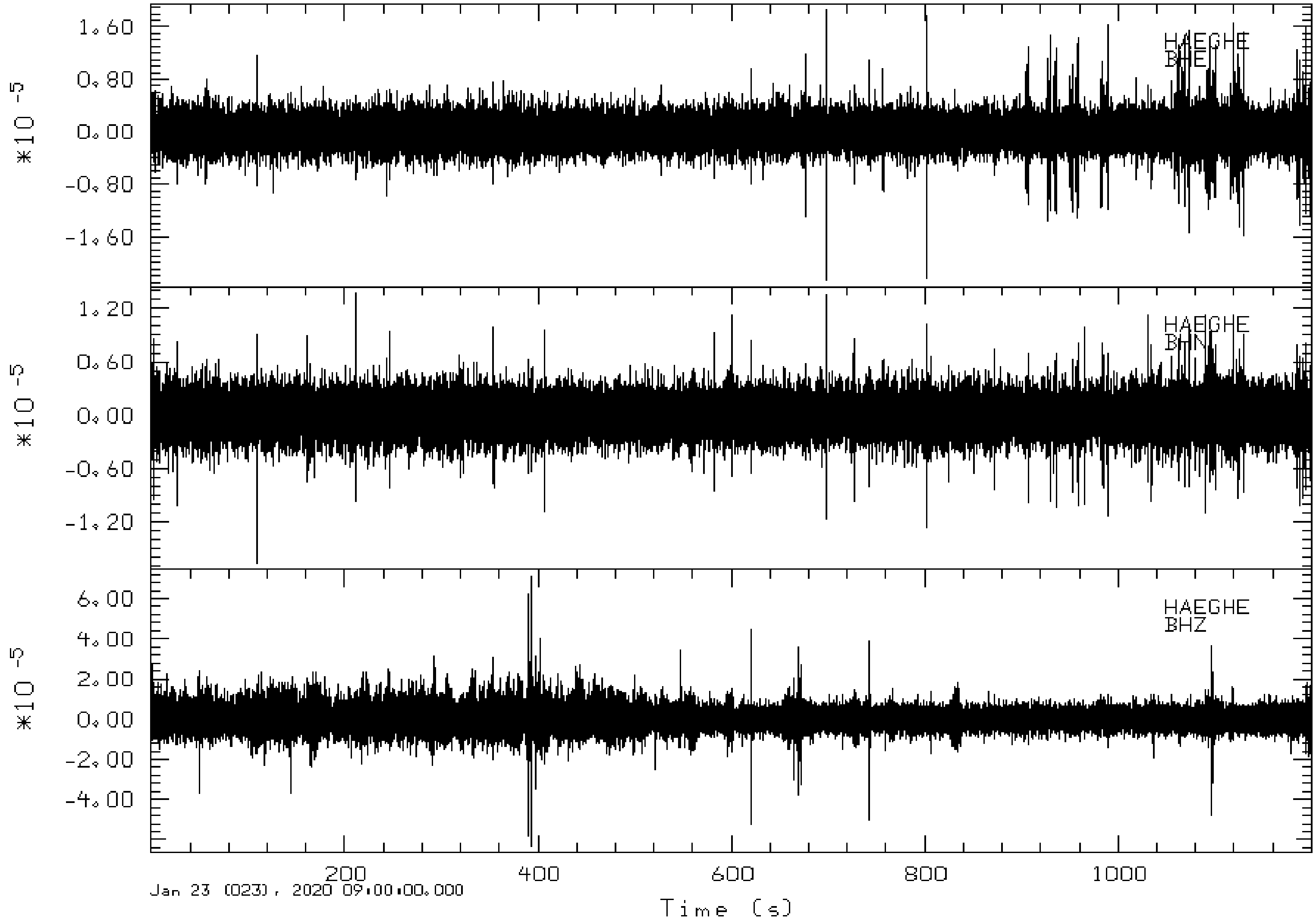
HAEGHE



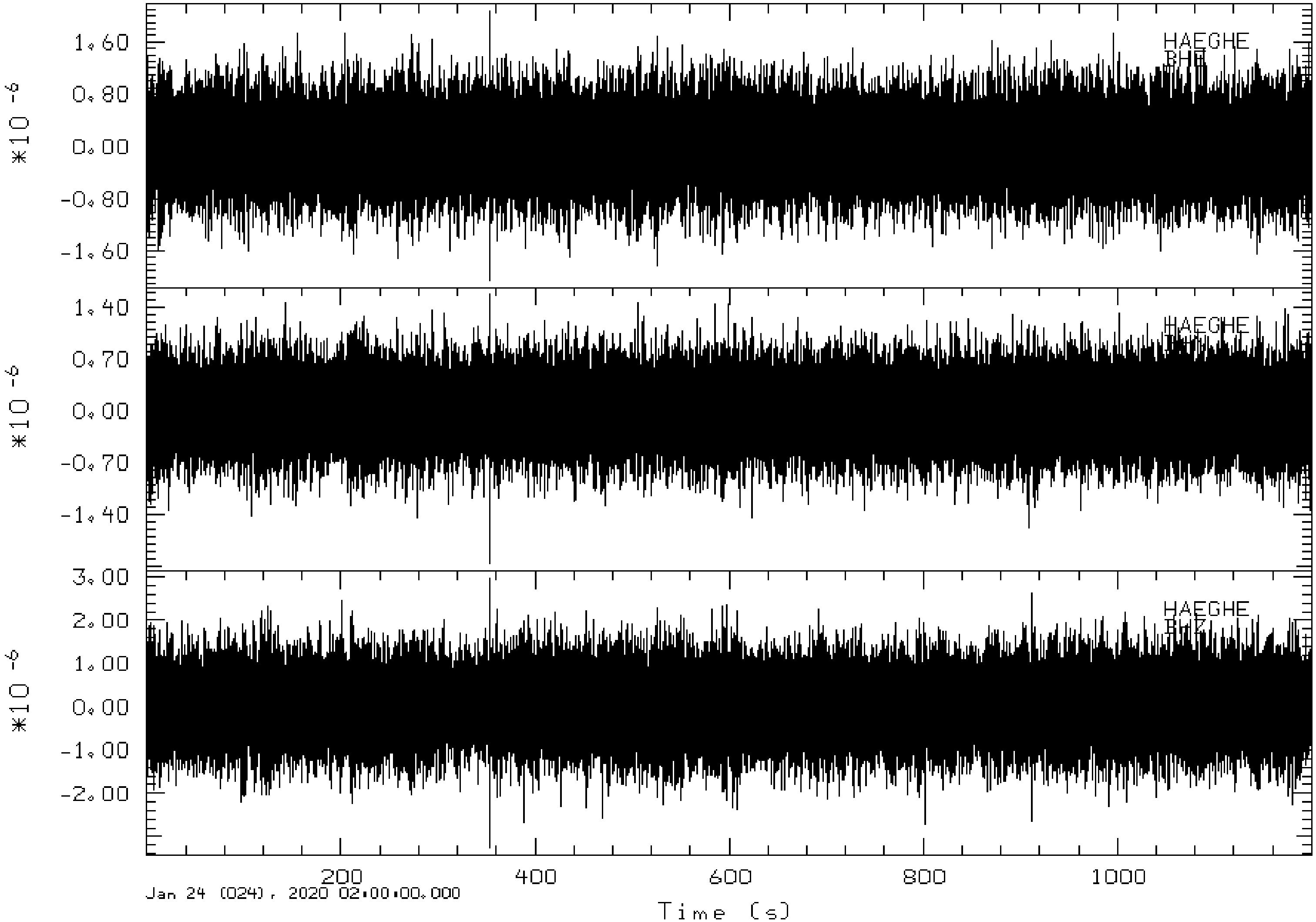
station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
HAEGHE Vertical Hourly Noise [m/s]
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/23/2020 8:00
1/23/2020 9:00
1/23/2020 10:00
1/23/2020 11:00
1/23/2020 12:00
1/23/2020 13:00
1/23/2020 14:00
1/23/2020 15:00
1/23/2020 16:00
1/23/2020 17:00
1/23/2020 18:00
1/23/2020 19:00
1/23/2020 20:00
1/23/2020 21:00
1/23/2020 22:00
1/23/2020 23:00
1/24/2020
1/24/2020 1:00
1/24/2020 2:00
1/24/2020 3:00
1/24/2020 4:00
1/24/2020 5:00
1/24/2020 6:00
1/24/2020 7:00
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

HAEGHE

HAEGHE - example of 20 minutes record during daily hours

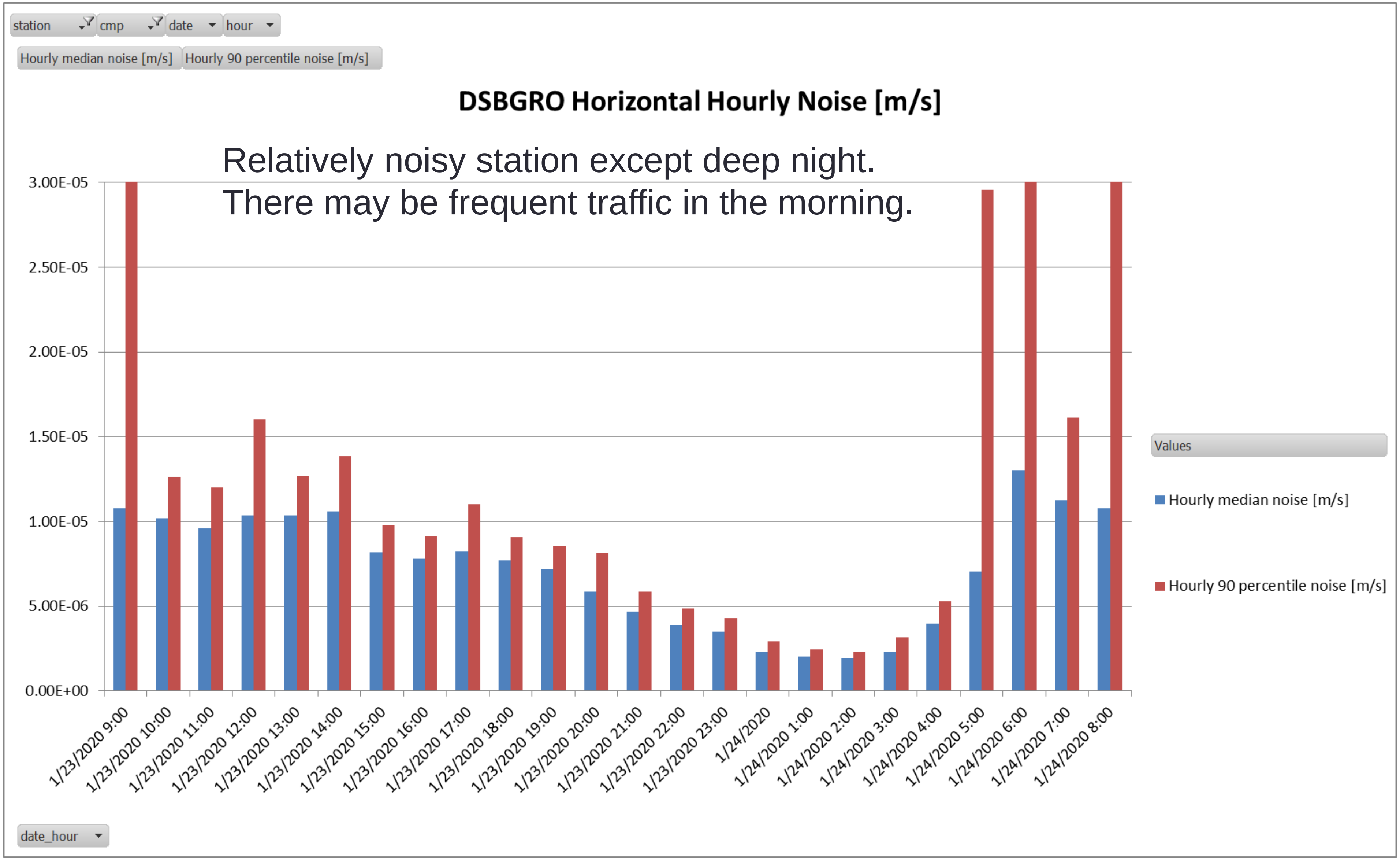


HAEGHE - example of 20 minutes record during night hours

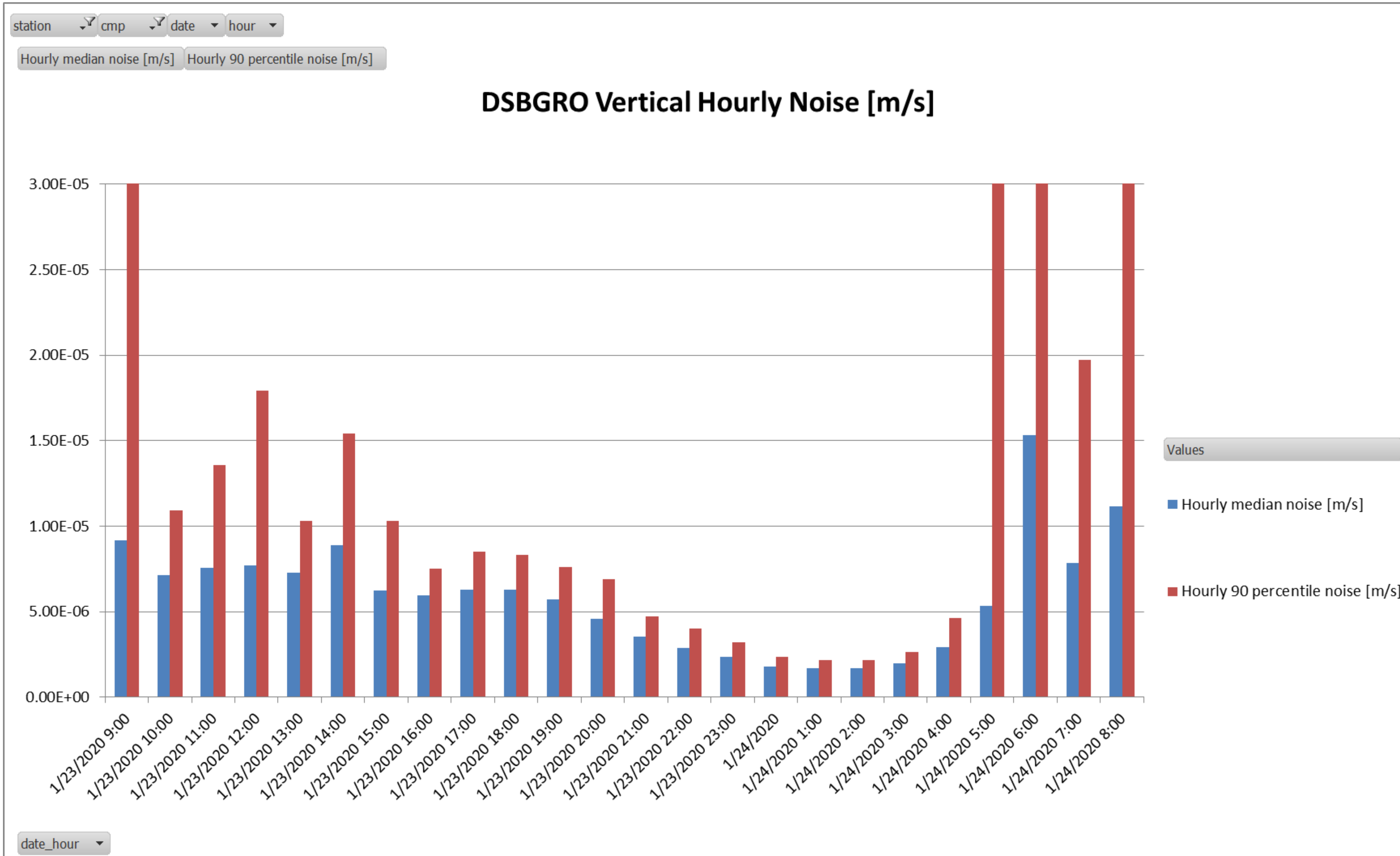


DSBGRO

Relatively noisy station except deep night.
There may be frequent traffic in the morning.



DSBGRO

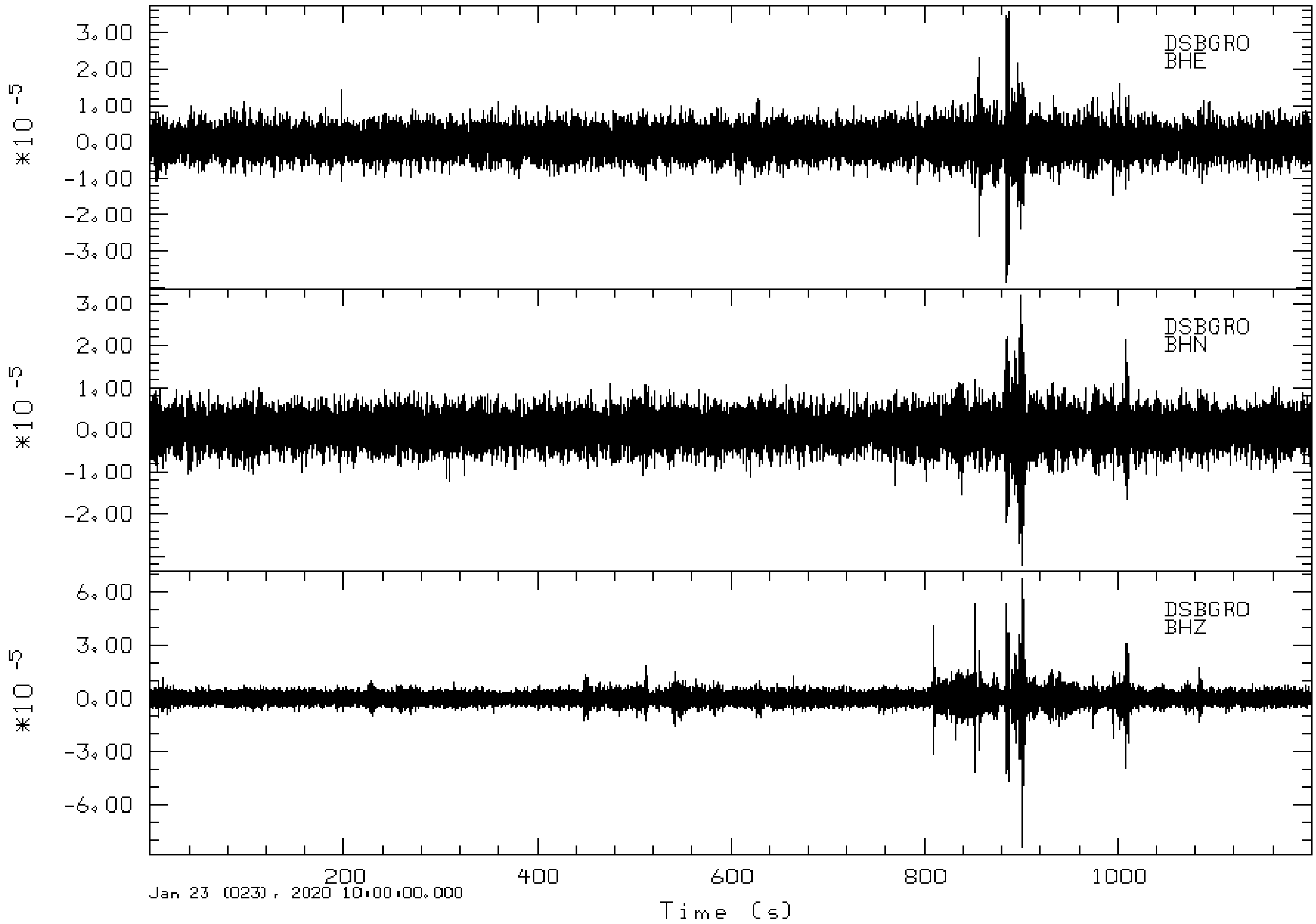


station
cmp
date
hour
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
DSBGRO Vertical Hourly Noise [m/s]
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
1/23/2020 9:00
1/23/2020 10:00
1/23/2020 11:00
1/23/2020 12:00
1/23/2020 13:00
1/23/2020 14:00
1/23/2020 15:00
1/23/2020 16:00
1/23/2020 17:00
1/23/2020 18:00
1/23/2020 19:00
1/23/2020 20:00
1/23/2020 21:00
1/23/2020 22:00
1/23/2020 23:00
1/24/2020
1/24/2020 1:00
1/24/2020 2:00
1/24/2020 3:00
1/24/2020 4:00
1/24/2020 5:00
1/24/2020 6:00
1/24/2020 7:00
1/24/2020 8:00
Values
Hourly median noise [m/s]
Hourly 90 percentile noise [m/s]
date_hour

DSBGRO

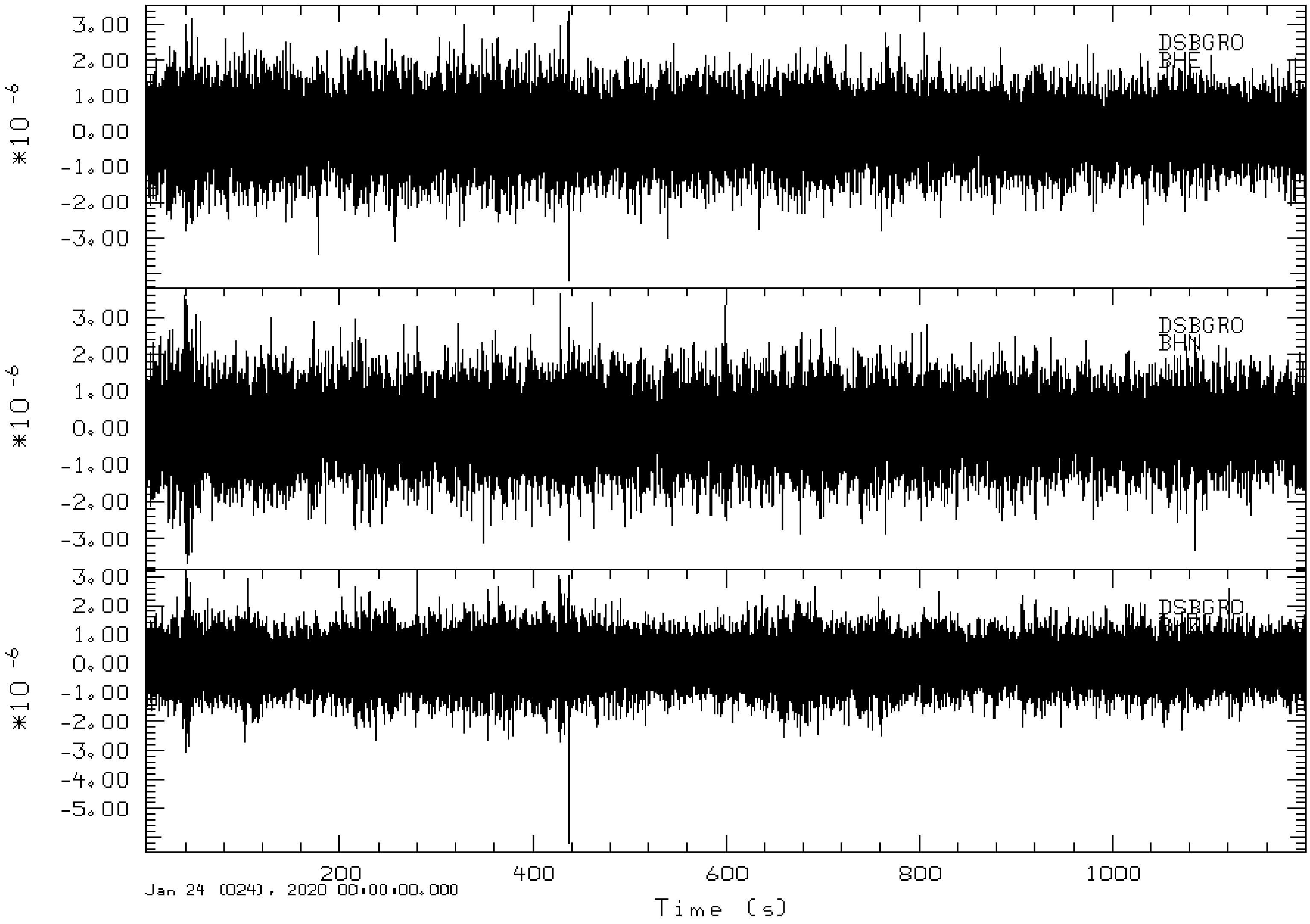
Seismik

DSBGRO - example of 20 minutes record during daily hours



DSBGRO

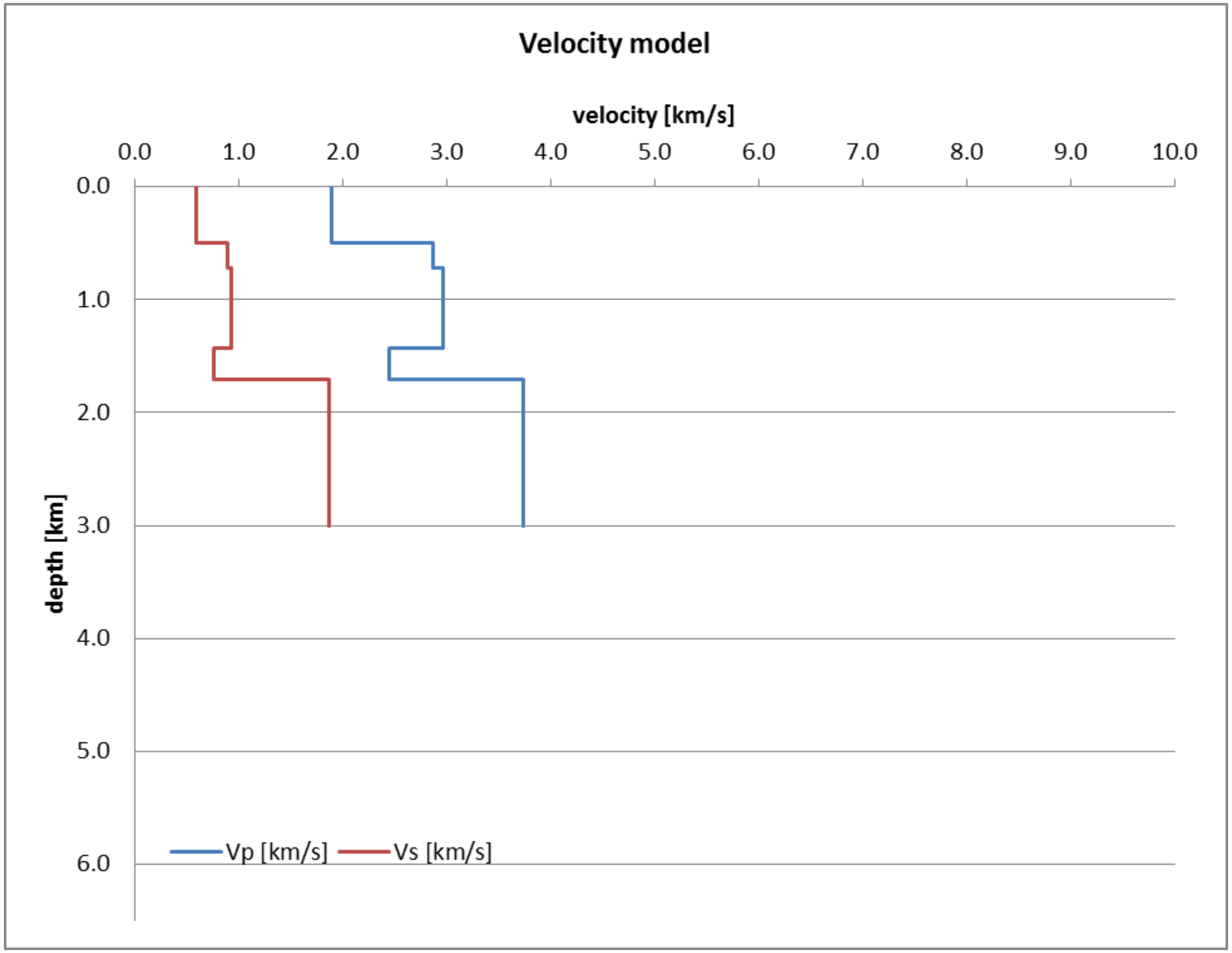
DSBGRO - example of 20 minutes record during night hours



Network performance modeling

Velocity Model

- The velocity model designed in October 2019 was used (based on best available data)
- P waves based on PanTerra 1D-model
- Vp/Vs derived from the Groningen gas field data



Network performance modeling

- **Velocity model:**
  - PanTerra 1D-model for P-waves
  - Vp/Vs from published data for Groningen field. Uncertainty.
  - P- and S-wave Q-factor: 70 – uncertain, probably not constant
- **Minimum number of station to detect an event:** 3 (minimum number to locate)
- **Minimum signal to noise ratio:** 2 (standard)
- **Target depth:** 2,000 m

- Results of the initial network modeling are presented on the following pages.
- Two sets of output are presented:
  - Minimum detectable magnitude. The level of magnitude assumes both P and S waves are above the level of noise.
  - Location accuracy (1-sigma probability) in horizontal and vertical direction. The location accuracy assumes both P and S waves are above the level of noise on all stations. For the earthquakes of magnitude just on the level of detectability the accuracy may be decreased.

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Measured noise levels – site characterization

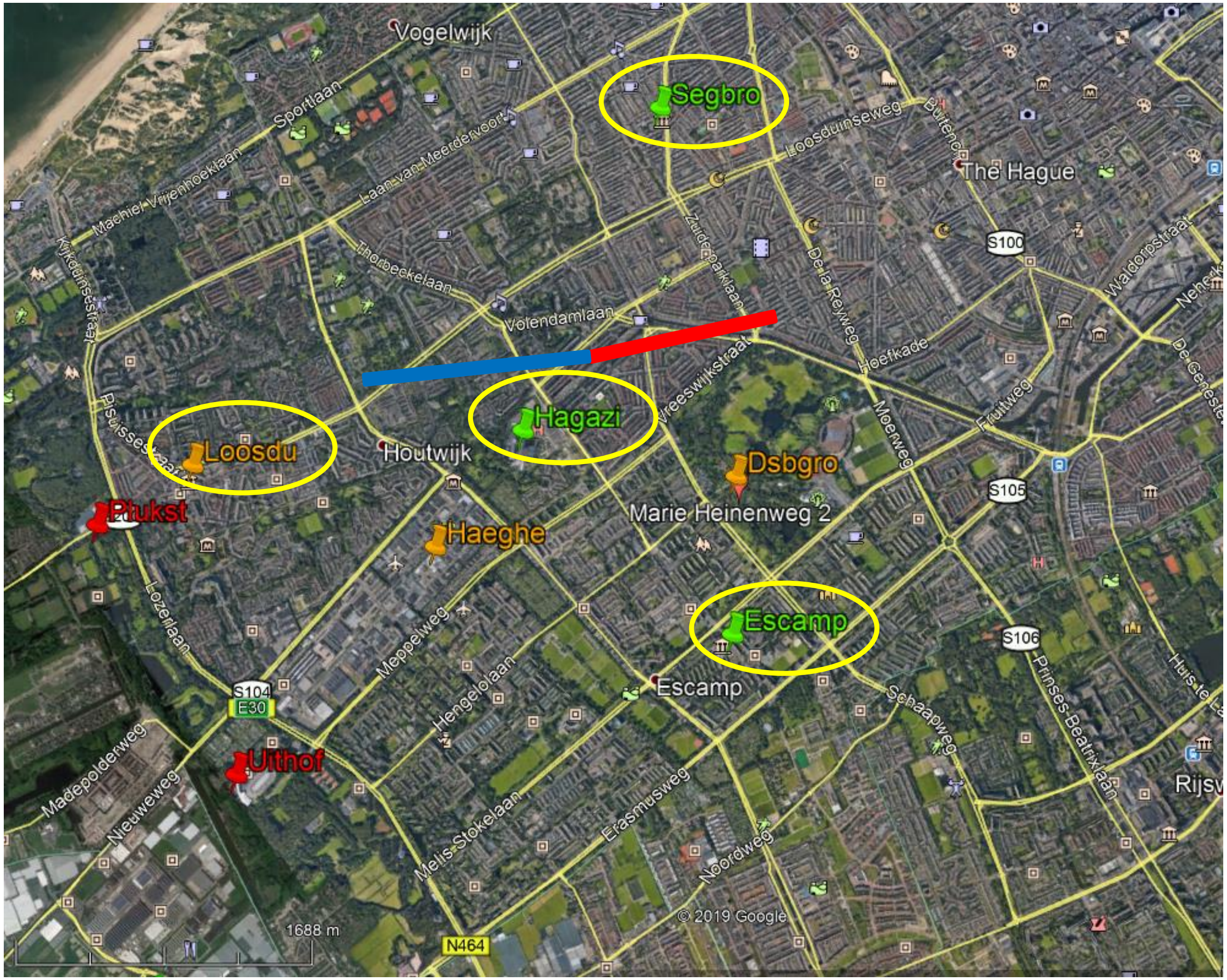
station	component	total_median	noise_m_s_09	Used
DSBGRO	Horiz.	7.37648E-06	1.19384E-05	Option II
DSBGRO	Vertical	5.61597E-06	1.11459E-05	
ESCAMP	Horiz.	3.47148E-06	7.68822E-06	
ESCAMP	Vertical	5.3156E-06	1.09994E-05	Option I, III
HAEGHE	Horiz.	3.22956E-06	7.51226E-06	
HAEGHE	Vertical	5.59544E-06	1.91711E-05	
HAGAZI	Horiz.	3.29991E-06	5.17224E-06	
HAGAZI	Vertical	9.49721E-06	1.51296E-05	Option I, III
LOOSDU	Horiz.	8.14903E-06	1.48928E-05	
LOOSDU	Vertical	1.57957E-05	2.94224E-05	Option I, III
PLUKST	Horiz.	1.28497E-05	2.67693E-05	
PLUKST	Vertical	7.77396E-06	1.91517E-05	Option II
SEGBRO	Horiz.	3.43192E-06	5.46807E-06	
SEGBRO	Vertical	7.37497E-06	1.18065E-05	Option I, II, III
UITHOF	Horiz.	1.06642E-05	3.66785E-05	
UITHOF	Vertical	1.84935E-05	4.43636E-05	Option II

- Three networks were tested for detectability and location accuracy.
- The stations were selected based on measured noise levels and geometry of the monitoring network.
- The 90th percentile of the 10 s maximum amplitudes for each station was used as noise level. The presented values represent detectability and location accuracy for 90% of time.
- The larger value of the horizontal / vertical component 90^{th} percentile was used.

Network Modeling I - Stations Overview

Seismik

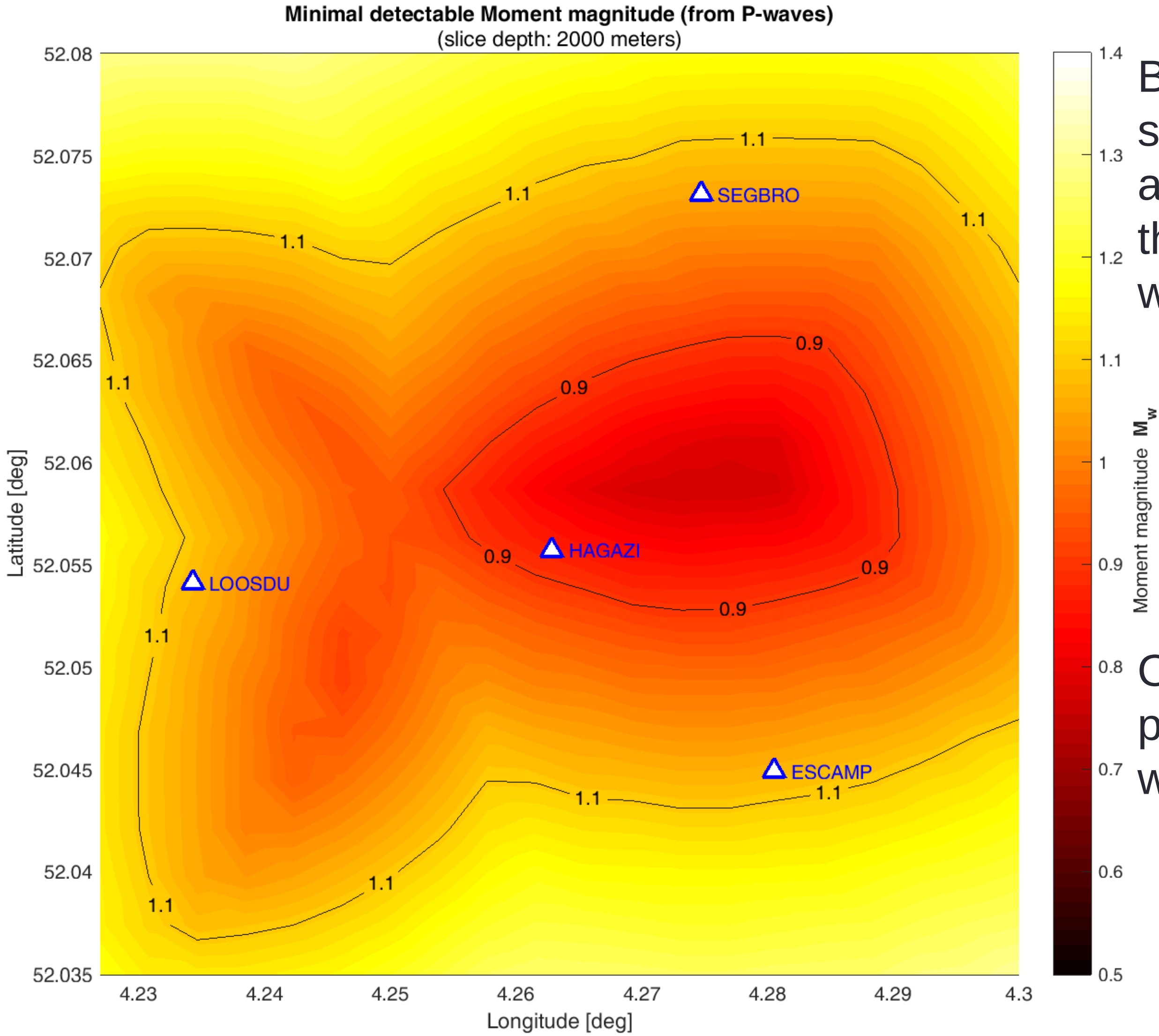
In the Option I four selected stations were used for the modeling. They form a correct design and are relatively quiet.



- Least noisy locations marked in green
- Medium noisy locations marked in orange
- Most noisy locations marked in red
- Red and blue lines show the paths of the planned geothermal wells

- Marked stations were used for the NetDesign version 1

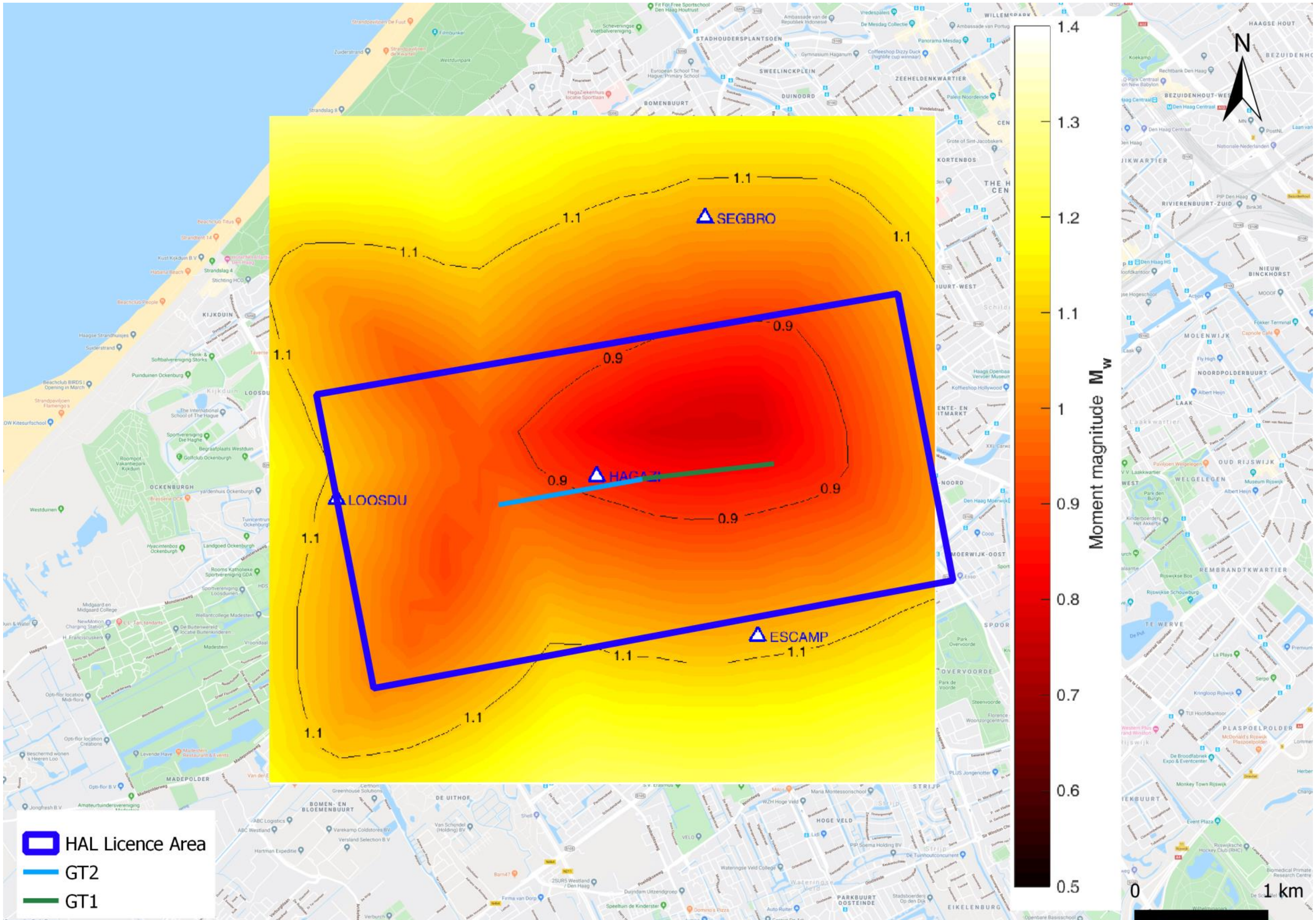
Network Modeling I - Minimum detectable magnitude



Best detectability of seismic events is achieved in the area of the planned geothermal wells.

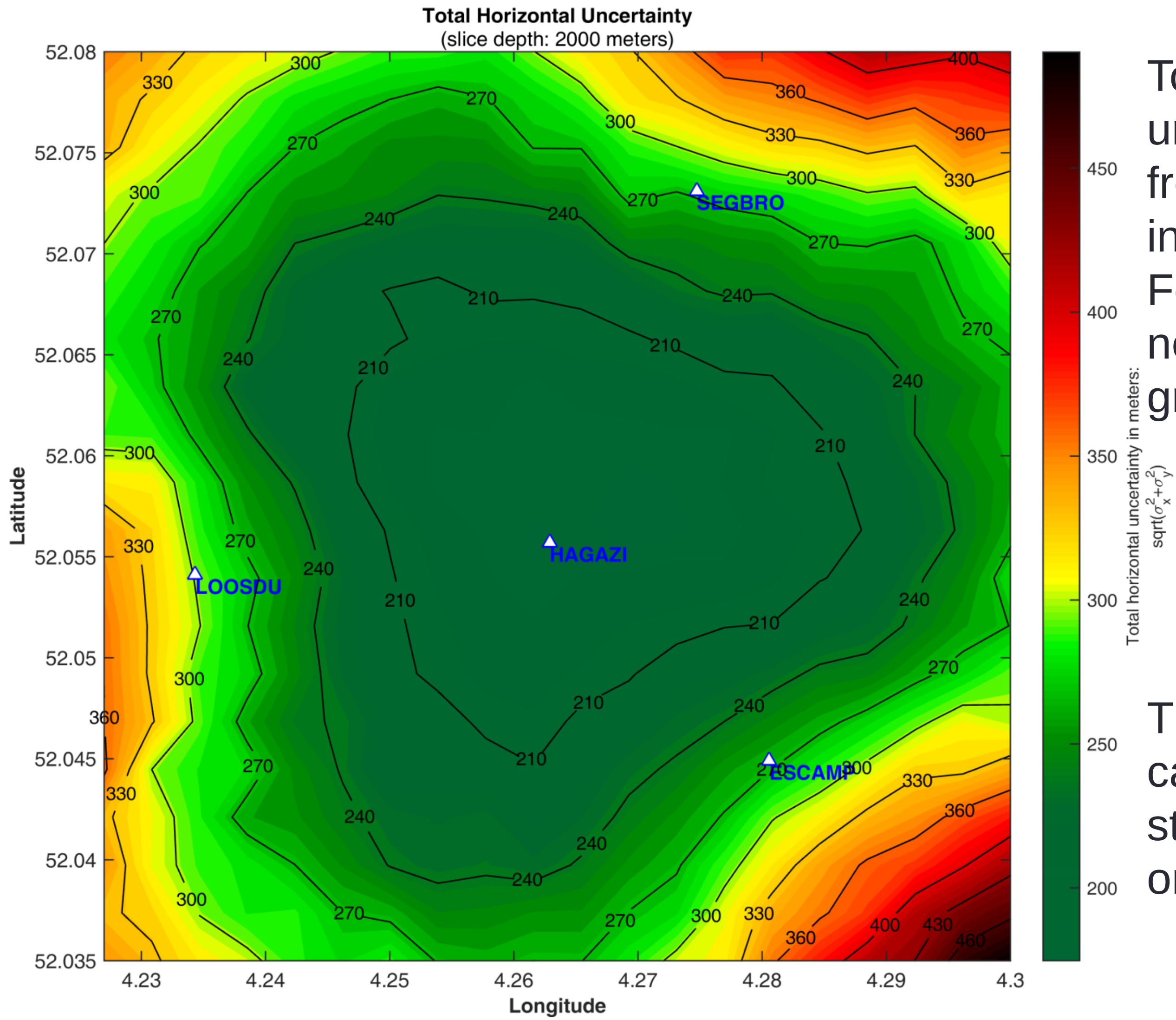
On the next slide the position of the planned wells is shown.

Network Modeling I - Minimum detectable magnitude



Network Modeling I - Horizontal Location Uncertainty

Seismik



Total horizontal uncertainty is increasing from the central stations in all directions.
For the area outside the network the uncertainty grows faster.

The uncertainty is calculated for relatively strong events detected on all four stations.

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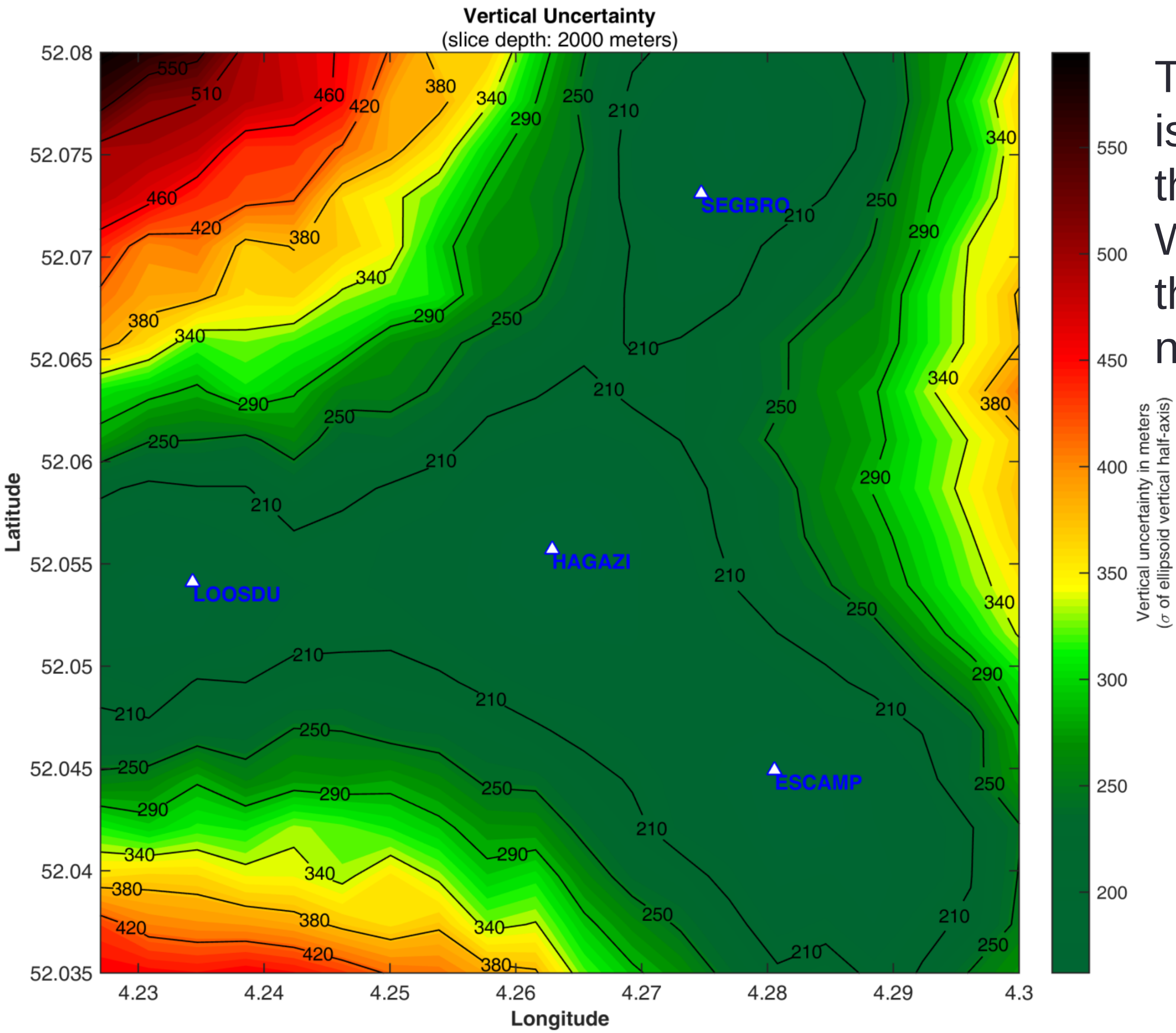
Network Modeling I - Vertical Location Uncertainty



The vertical uncertainty is lowest in the vicinity of the stations.
With the central station the whole area inside the network is well covered.

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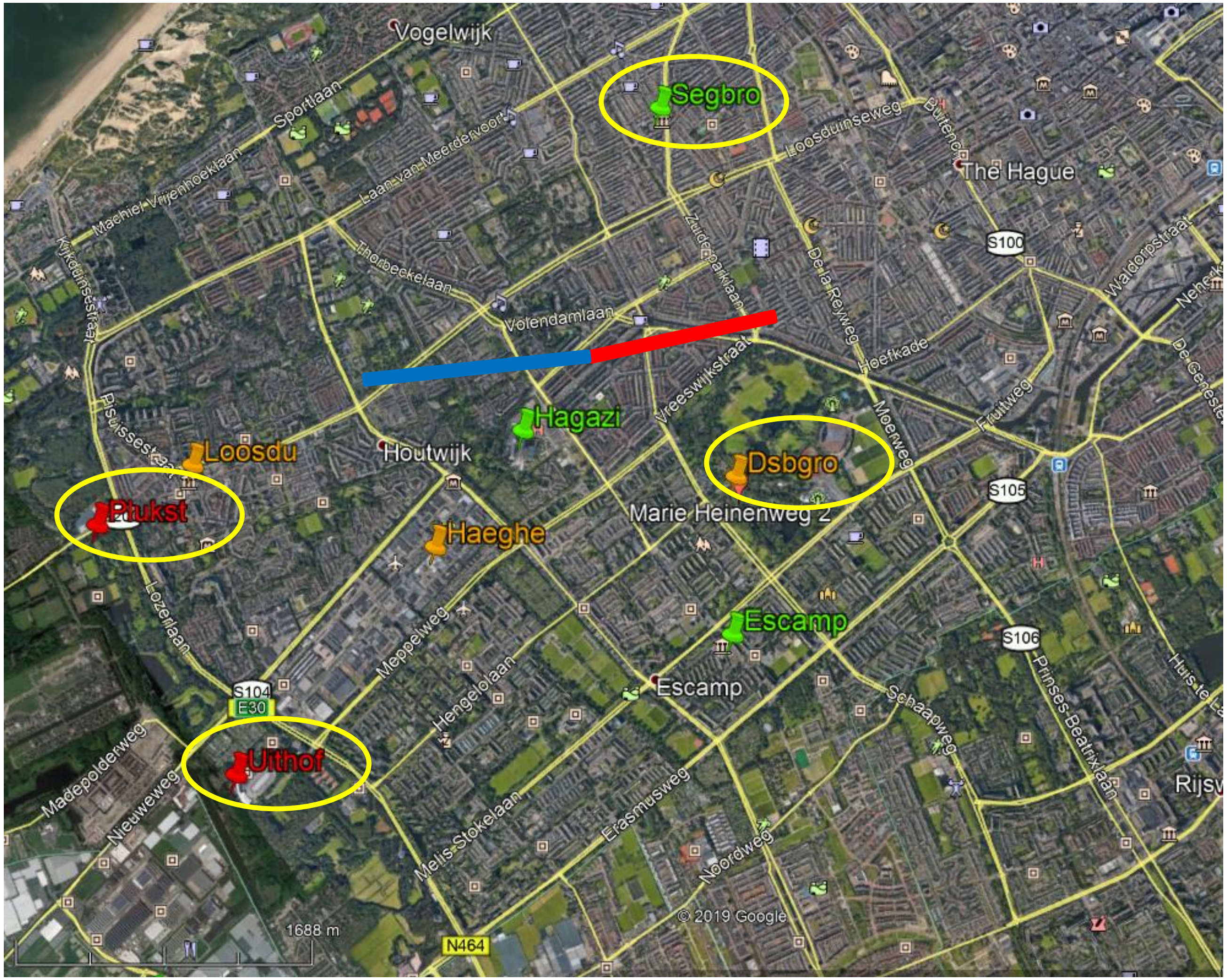
Network Modeling II - Stations Overview

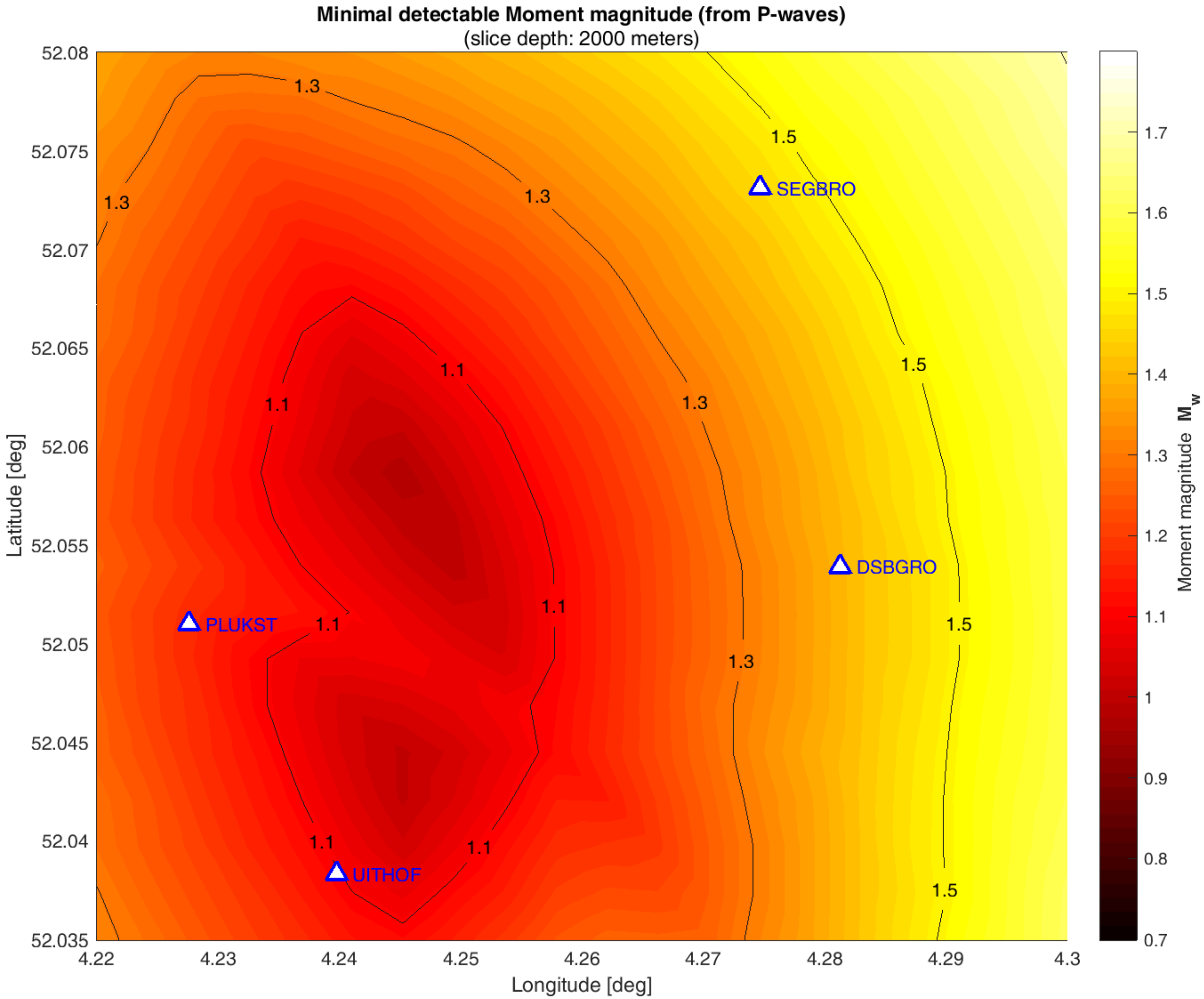
In the option II four alterative stations were used for the modeling. They are more noisy but can be alternatively used.



- Least noisy locations marked in green
- Medium noisy locations marked in orange
- Most noisy locations marked in red
- Red and blue lines show the paths of the planned geothermal wells

- Marked stations were used for the NetDesign version 2

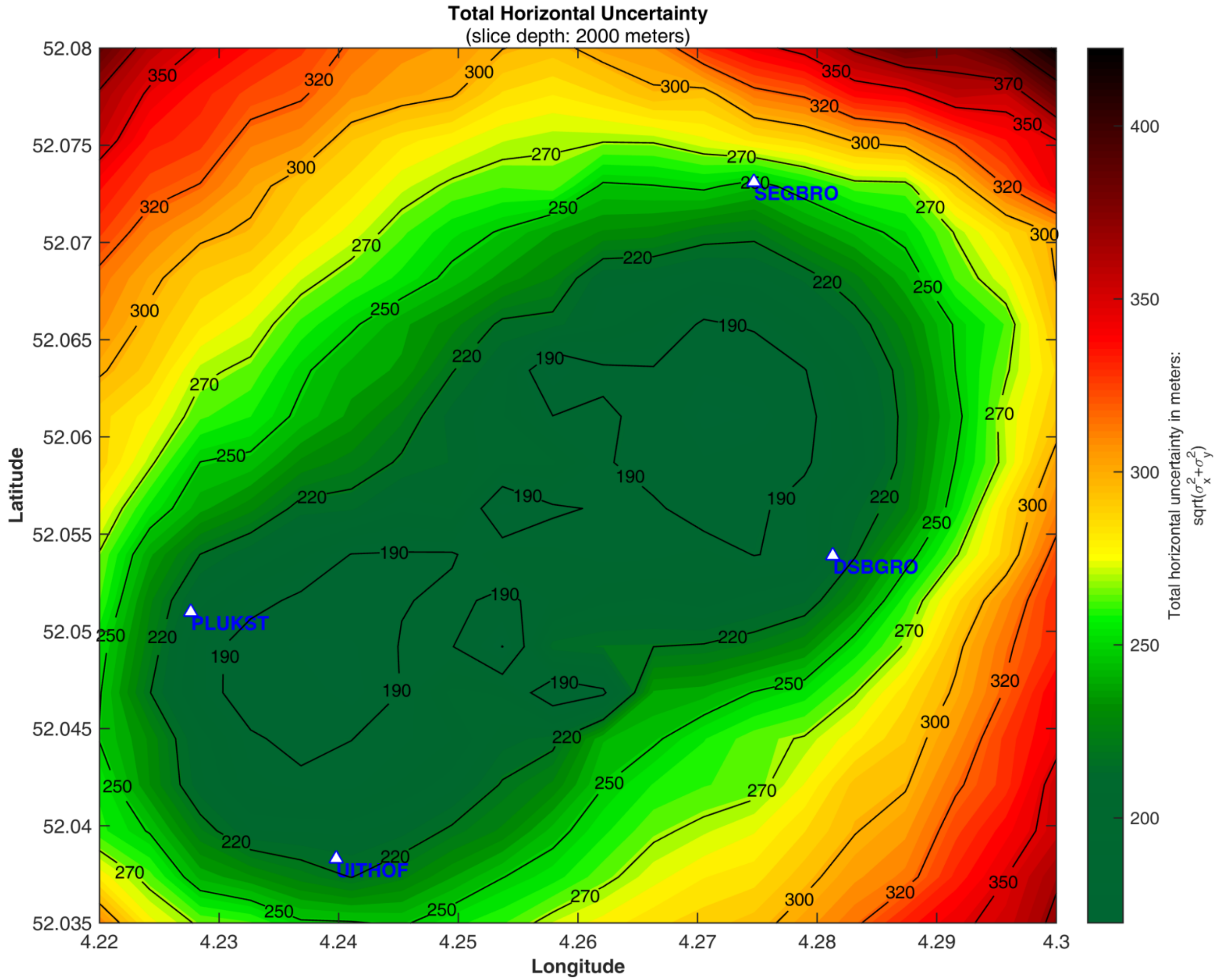
Network Modeling II - Minimum detectable magnitude



Best detectability of seismic events is achieved close to the noisy stations on the West. The reason is that the signal must be visible on at least 3 stations. Noisy stations are able to detect close events but not further ones of the same magnitude.

Network Modeling II - Horizontal Location Uncertainty

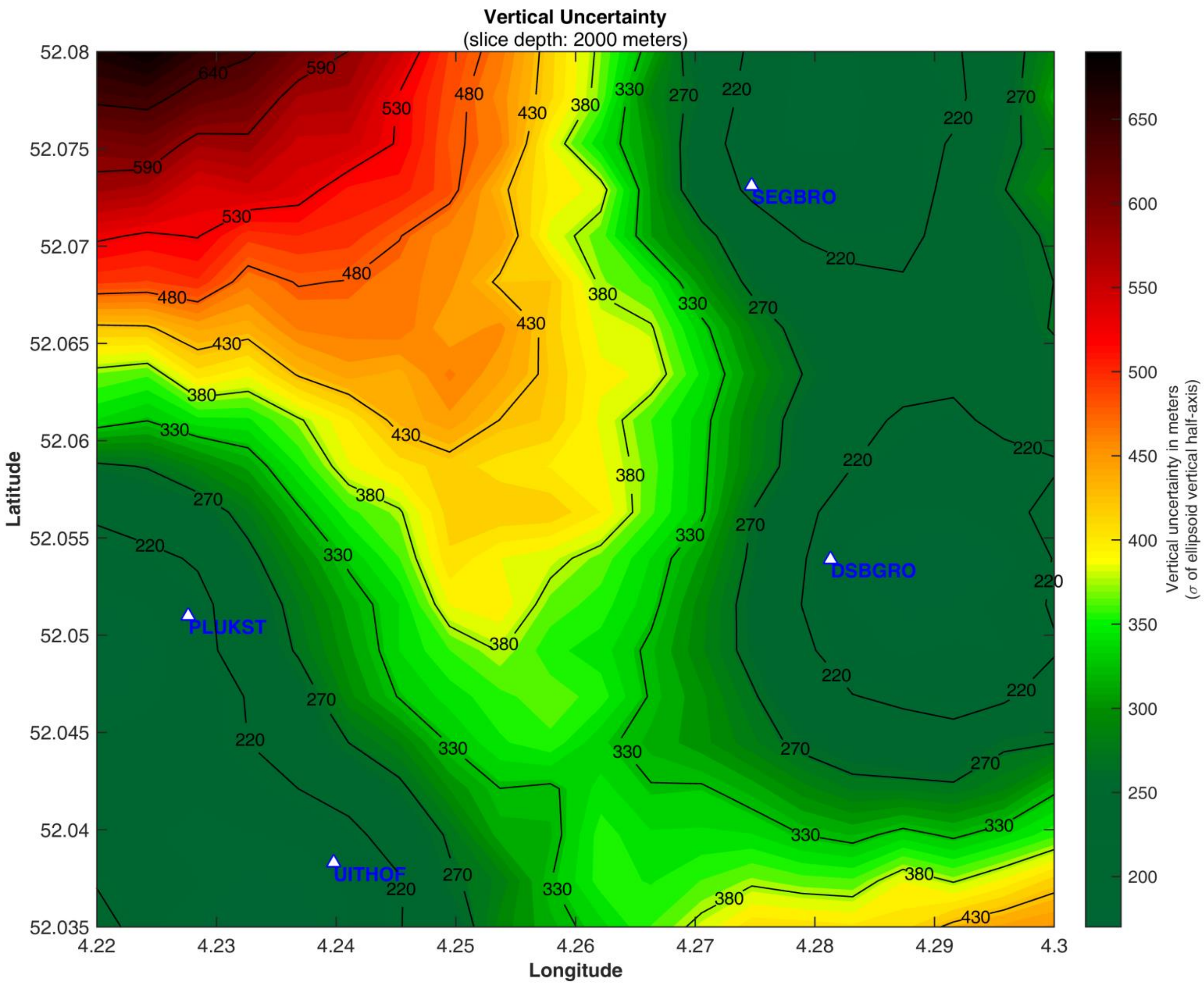
Seismik



Relatively low horizontal uncertainty is achieved inside the network.

The uncertainty is calculated for relatively strong events detected on all four stations.

Network Modeling II - Vertical Location Uncertainty



The vertical uncertainty is lowest in the vicinity of the stations.
In the central part of the network the vertical uncertainty increases partly.

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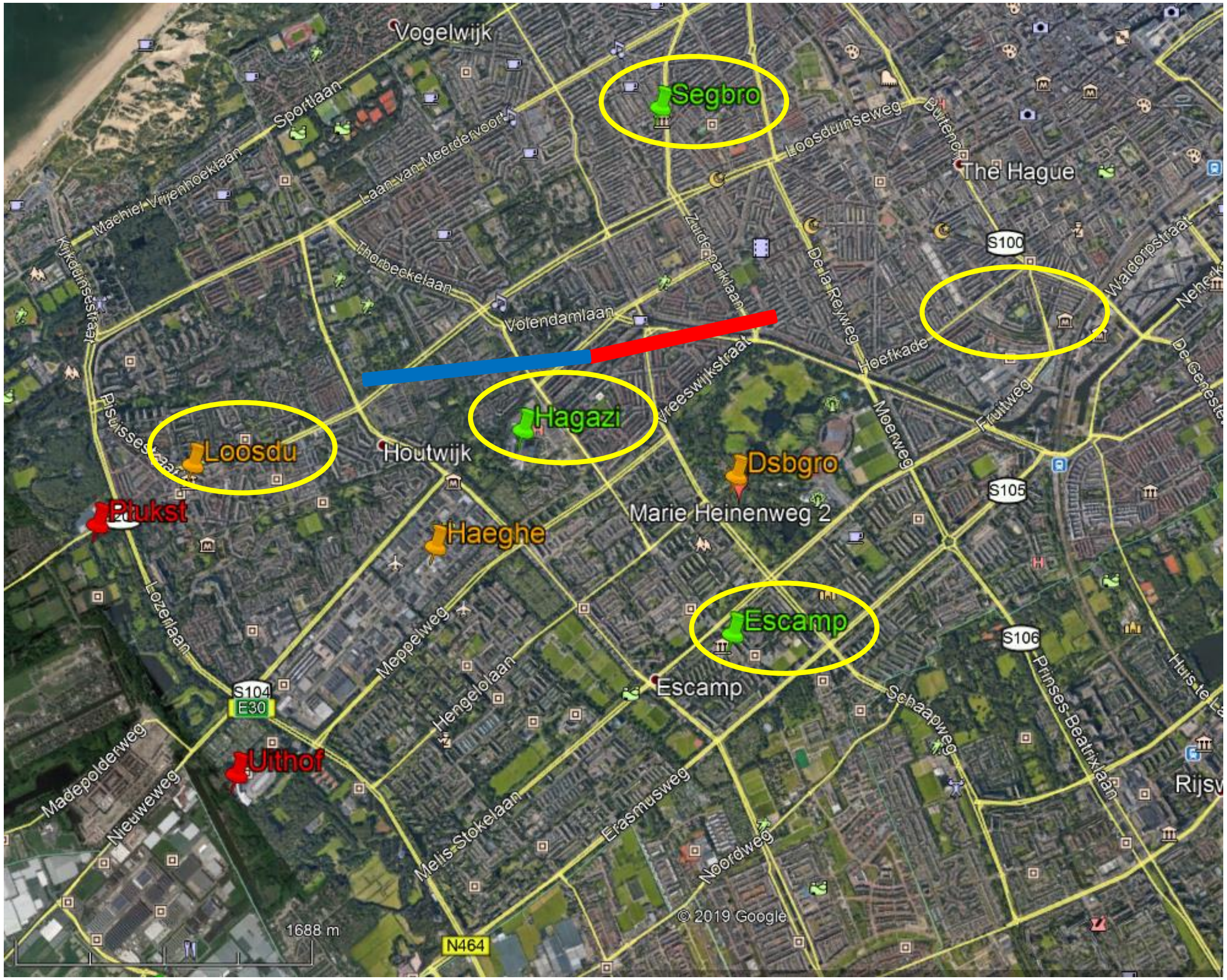
Network Modeling III - Stations Overview

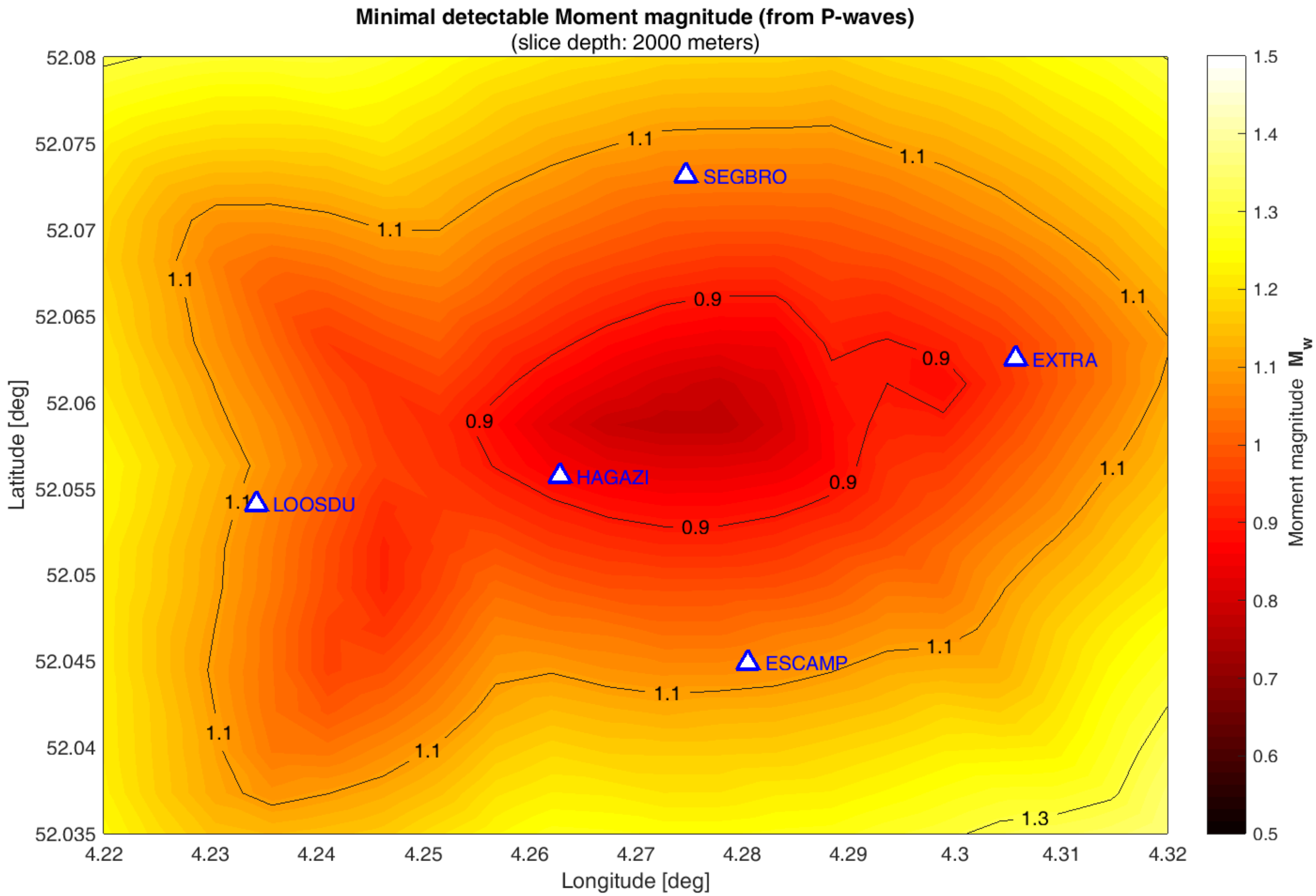
Option III consists of five stations – one added to the option I. The level of noise was not measured at the most eastern proposed site, noise level of the Loosdu site was used.



- Least noisy locations marked in green
- Medium noisy locations marked in orange
- Most noisy locations marked in red
- Red and blue lines show the paths of the planned geothermal wells

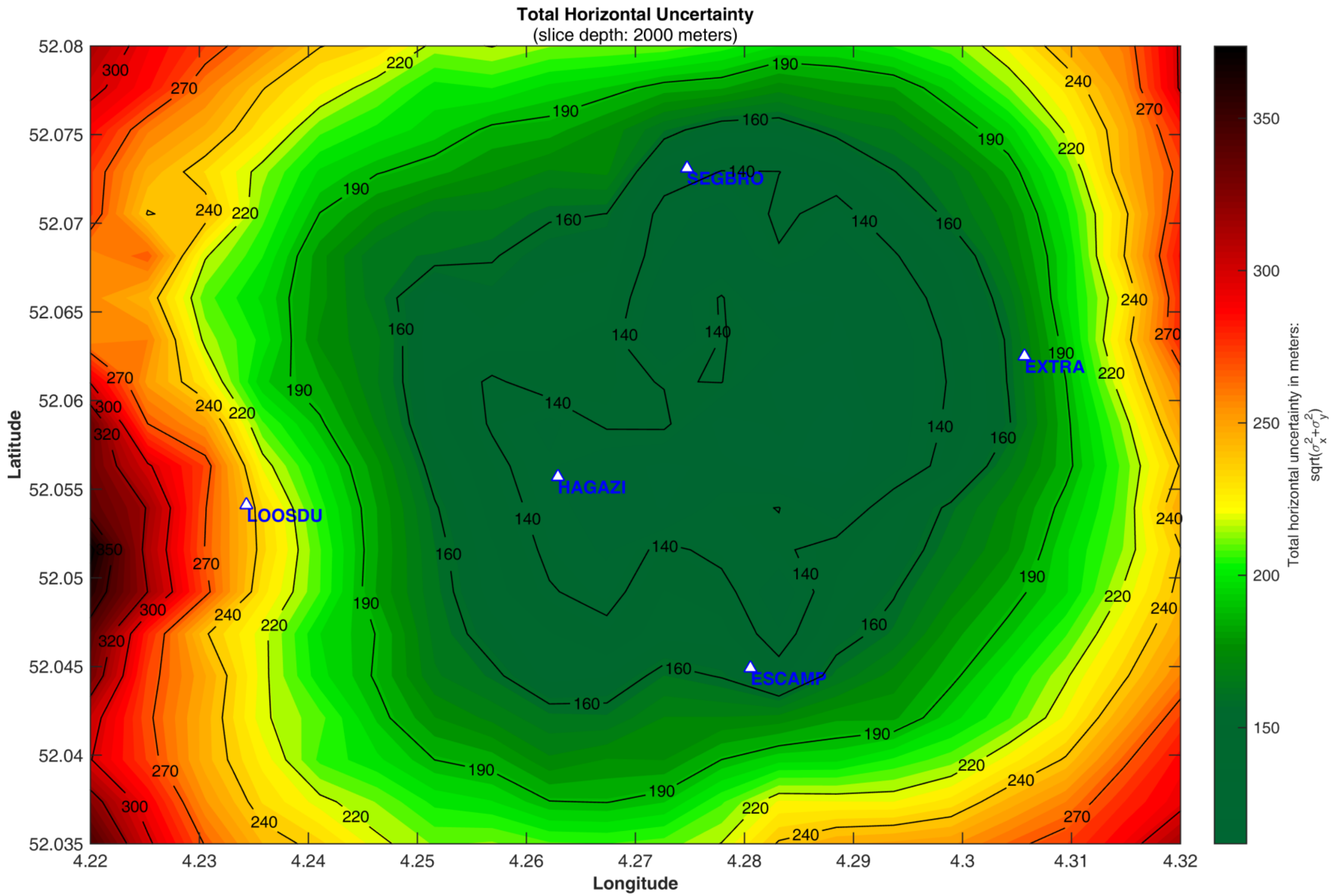
- Marked stations were used for the NetDesign version 2

Network Modeling II - Minimum detectable magnitude



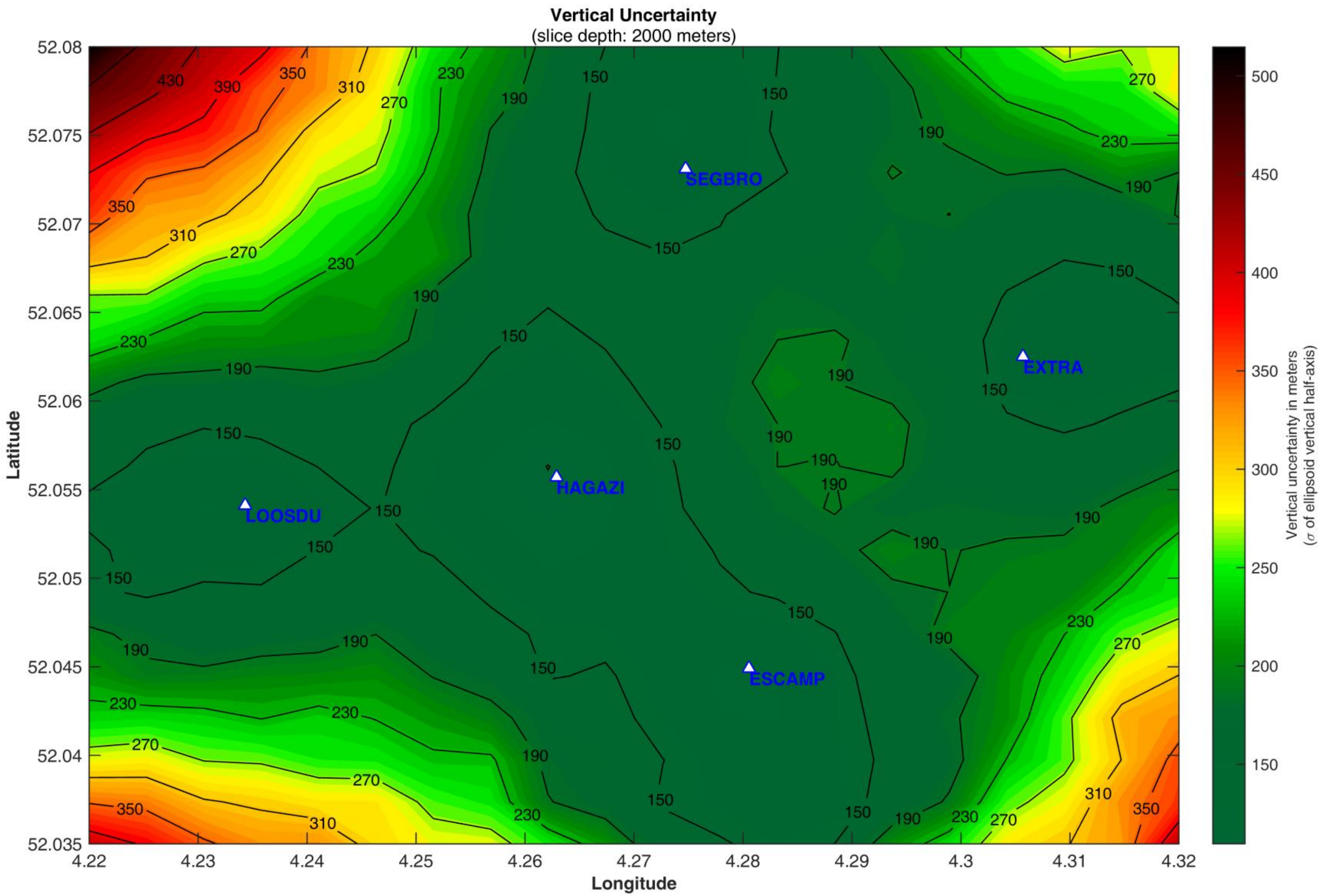
Adding the fifth station improves the detectability in the Eastern part.

Network Modeling III - Horizontal Location Uncertainty



Decreased horizontal uncertainty inside the network using five stations.

Network Modeling III - Vertical Location Uncertainty



Decreased horizontal uncertainty inside the network using five stations. The vertical uncertainty is lowest in the vicinity of the stations.

Comments and conclusions

- Four selected stations in the Option I form a network which is supposed to detect all seismic events of moment magnitude 0.9-1.1 or larger in the area of interest.
- In times of decreased noise (e.g. at night) even weaker events can be detected.
- The 1-sigma location uncertainty of the events recorded on all four stations is up to 300 m in both horizontal and vertical direction.
- Other two alternative networks were tested. Option II shows the results of the four-station network where some of the more noisy locations were used. This network has slightly worse performance. All eight locations for the noise measurement were selected on relatively quiet places thus the noise difference is not very large.
- Option II shows the results of the five-station network where an additional station was added to the East of the planned wells. Noise level on the site was only estimated. Both detectability and location accuracy was improved in larger area. The network is also more robust with 5 stations.

Observations and notes

- Locations having solid concrete base bellow (e.g. underground parking places) have generally less noise then locations like sheds or simple buildings. Putting a solid concrete base bellow some stations (Plukst, Uithof) could reduce the noise they register.
- It is possible that in some cases proper filtering can reduce the noise without eliminating the signal. The frequency analysis will be yet done.
- More networks can be tested.