Reviewers' comments are shown in blue text and our responses are in black text.

Reviewer A:

The present manuscript of Shiddiqi et al. aims to improve the monitoring in the North sea, which is currently based on a network of land-based stations, by expanding the network with three OBS sensors and applying a deep-learning algorithm to expand the earthquake catalog. Understanding the background seismicity and developing robust detection methods and constraints on locations is important for monitoring CO2 sites distinguishing natural seismicity from events related to injection.

Overall, the manuscript is well written and well accessible for readers with different backgrounds. The methods used are solid and the figures are nice and informative.

From Figure 8 it is clear that the authors are improving the results by detecting more low magnitude events, but it is not clear to me what is improving the results, whether it is the three OBSs or the different processing. It would also depend on where the events are located? Would it make sense to do the same processing with and without the OBSs, similar to what is done for the location to compare?

Response:

We thank the reviewer for this comment. To clarify the contribution of the different methods, we compared the EQTransformer results using (1) only land-based stations and (2) a combination of land stations and OBSs. Using EQTransformer with land stations alone resulted in 137 additional events, while the inclusion of OBS data increased this number to 154 events. This comparison shows that most of the reduction in magnitude of completeness is associated with the machine-learning-based detection workflow, while the OBS contribution to the number of detected events is more modest. The relatively small increase is likely related to the high noise levels at the OBS sites and the fact that much of the seismicity occurs closer to the coast, where land stations already provide good detection capability. We revised the manuscript to clarify the distinct contributions of EQTransformer and OBS data.

We have added the following text in Section 4 Earthquake Data Processing (Lines 202-207)

"After removing these non-natural events, the combined EQTransformer analysis using both OBS and land stations resulted in 154 additional events. For comparison, applying EQTransformer using only land stations resulted in 137 additional events. The relatively modest increase associated with the OBS data likely reflects the higher noise levels at the OBS sites and the concentration of much of the seismicity closer to the coast, where land stations already provide good detection capability."

For the timing of the OBSs, noise cross-correlations were used. Can you add a sentence on how this works in the manuscript? Does the seasonal variation in noise sources or localized anthropogenic noise affect the measurements? For the curved CCFs, can you see anything in the spectrogram for this time period?

Response:

Time correction:

We have added the following sentence to describe how we applied time correction to the continuous seismic data (Lines 106-107):

“The ambient noise cross-correlation shows that the time drifts are linear and match with the skew measurement (Table 1). Therefore, we decided to use the skew measurement to correct for the continuous seismic data.”

We included table 1 showing comparison of time drift from skew measurement and ambient noise correlation, which was previously in the supplementary material.

Table 1 Time correction for OBSs obtained from skew measurement and ambient noise cross-correlation

Station	Skew (seconds)	7-day stack (seconds)	daily EGF (seconds)
HNO1	-29.446	-28.9	-29.4
HNO2	-3.0199	-3.0	-3.0
HNO3	-0.4220	-0.4	-0.4

Seasonal variation of the seismic noise and curved cross-correlation functions:

The temporal variation Power Spectral Density (PSD) of seismic noise for the whole deployment is presented in Figure 1 below. At a frequency between 0.1 to 0.5 Hz, we see stronger noise amplitude during the first half of the deployment (November 2021 to March 2022; which corresponds to late autumn 2021 to early spring 2022). This time period also coincided with the curved CCF, which can be explained by the oceanic weather conditions during this time period, e.g., occurrence of storms. As shown in Figure 2 below, we see some variation in the spectogram, but overall we don't see a significant change in the spectrogram of CCFs.

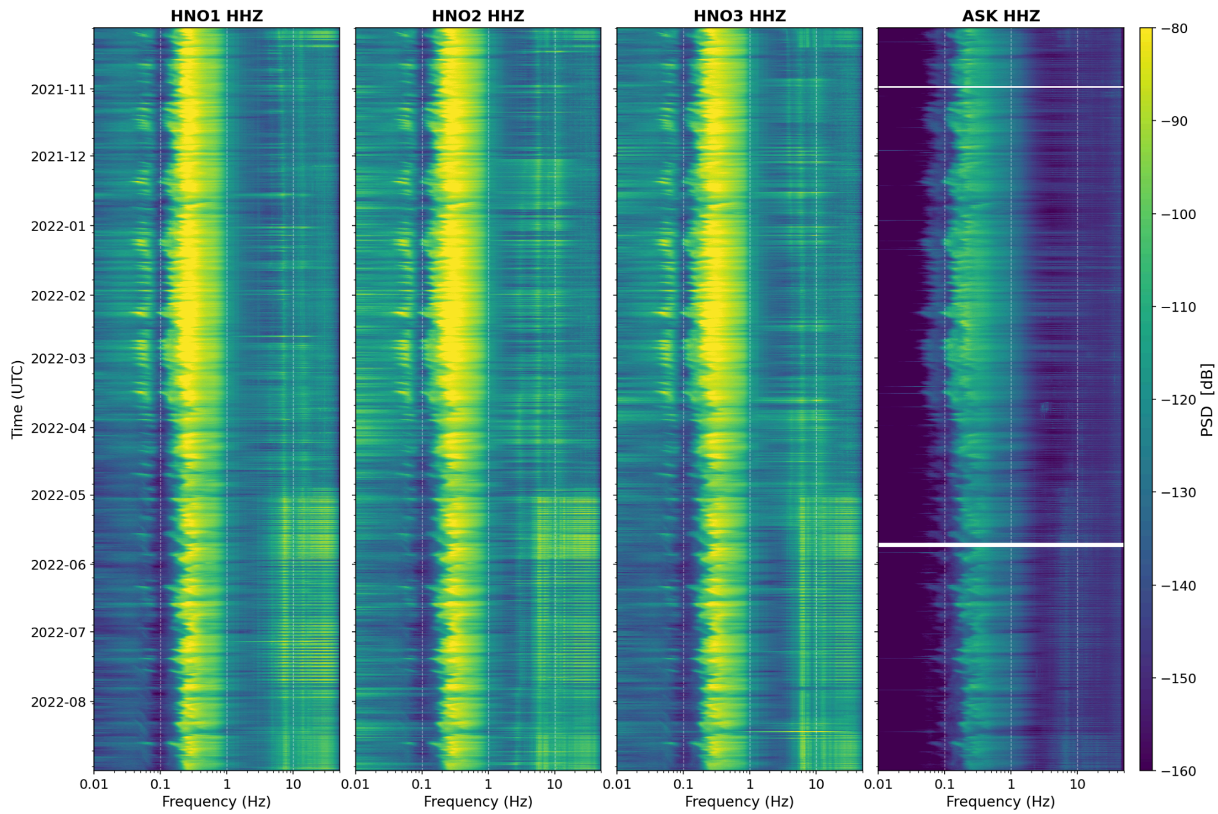

Figure 1. Temporal variation of noise PSD for all three OBSs measured on the vertical channels (HHZ). The noise PSD is presented here is the median value every six hours.

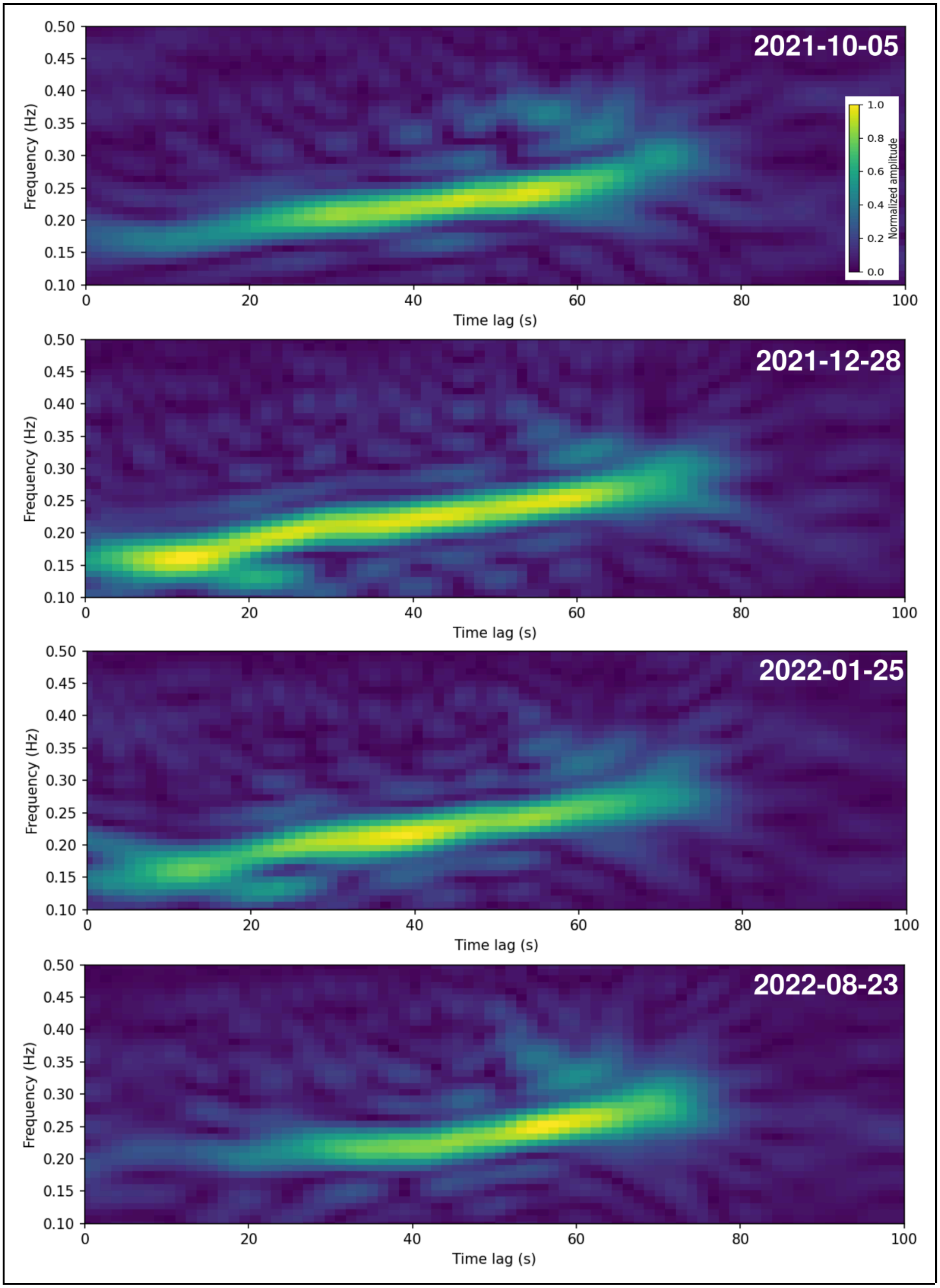
2021-10-05
2021-12-28
2022-01-25
2022-08-23
Frequency (Hz)
Time lag (s)
Normalized amplitude
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0
20
40
60
80
100
1.0
0.8
0.6
0.4
0.2
0.0

Figure 2. Spectrogram of stacked CCFs (14 days stack, the first day in each stack is shown in the upper right of each panel) for four different times, including during the curved CCFs (2021-12-28 and 2022-01-25).

277: Does the seasonal variation in noise levels have an effect on your detection capability?

Response:
Strongest seasonal variation are below 1 Hz, which is lower than the frequency ranges used in earthquake detection

314: How would the DAS compare to the OBSs in terms of noise levels?

Response:

Direct quantitative comparisons between submarine DAS and OBS noise levels remain limited in the literature. We therefore added a short discussion and references to recent studies comparing DAS and OBS observations, showing that DAS signal quality is generally more spatially variable and sensitive to environmental conditions and cable coupling, while OBS recordings provide more stable measurements of ground motion.

We added the following text (lines 333-339):

While DAS can capture seismic signals comparable to conventional instruments when deployed near the source region, recent studies indicate that its signal quality is more spatially variable and sensitive to environmental conditions, cable coupling, and source–receiver geometry (e.g., Frazao et al 2026, Armas et al. 2026). For example, comparisons with ocean bottom seismometers (OBS) show that DAS observations can provide useful seismic information but typically require calibration, filtering, and selection of high-quality channels due to variable noise conditions. In contrast, OBS recordings provide more stable point measurements of ground motion, making the two approaches complementary for offshore monitoring.

272/310/325: “small number” how many would you recommend? How much of the improvement is from the new processing and the new sensors?

Response:

The optimal number of OBS stations depends on the monitoring objectives and network geometry, so we prefer not to recommend a specific number based on our temporary three-station deployment.

337 and Figure 8: Reducing the magnitude of completeness from 1.1 to 0.8, can you compare when the method is different?

Response:

As discussed in the previous response, we compared the EQTransformer results using land stations only and using the combined land-OBS dataset. The comparison indicates that most of the reduction in magnitude of completeness is associated with the machine-learning-based detection workflow, while the OBS contribution to the number of additional detections is relatively modest. We have revised the manuscript to clarify this distinction.

Reviewer B:

Dear authors, dear associate editor

This document constitutes my review of the manuscript "*Improving seismicity monitoring to prepare for CO2 storage in the Horda platform, Norwegian North Sea*" by the above listed author.

Overview: The manuscript describes a temporary ocean bottom seismometer deployment in the Norwegian Sea with the aim to improve detection capability and location uncertainty in an area slated for CO2 in the near future. The authors carefully derive the sensor orientations, a local 1D velocity that help explain the Green functions observed, and detect and locate regional events. The analyses show that event detection is improved and the magnitude of completeness is reduced. Location uncertainties are also improved, clearly underscoring the importance of added seismic monitoring offshore for the proposed CO2 sequestration projects. The manuscript is clearly and well written, the explanations of the analyses and methodologies used are also clear and concise. In all, I think this paper is a timely and useful contribution to Seismica.

Main concerns:

The analyses are clearly useful and the addition of the OBSs clearly improve the detection and location abilities. However, the current methodologies applied do not directly confirm the improved detection, as 1) detected events on the on-land network were augmented by picks on the OBS; and 2) EQTransnformer was used with all stations, OBS and on-land. The analyses could be strenghtened by, for example, comparing the results of EQTransformer with and without the OBSs included to get at detection improvements alone.

Response:

We thank the reviewer for this helpful suggestion. Following the recommendation, we compared EQTransformer detection results using land stations only and using the combined OBS and land-station dataset. EQTransformer applied to land stations alone detected 137 additional events, whereas inclusion of the OBS data increased the number to 154 events. This indicates that the main improvement in detection capability and reduction in magnitude of completeness results from the machine-learning-based detection approach itself, while the OBS contribution to the number of newly detected events is relatively modest. However, as discussed in the later part of the manuscript, the OBS data provide important improvements in offshore earthquake location constraints and azimuthal coverage. We revised the manuscript accordingly to better distinguish improvements related to detection from those related to location accuracy.

The writing, while clear and concise, changes from active to passive voice throughout. I suggest picking one and sticking with it throughout.

Response:
We thank the reviewer for this suggestion. We revised the manuscript to improve consistency in writing style and reduce several awkward passive constructions

The analyses of Scholte waves is clear and concise and explains parts of the waveforms at the OBS station. However, the resulting 1D velocity refinements are not used in the location of events in the later part of the manuscript. While useful information it currently does not support the overall aim and findings of the manuscript. I appreciate the inclusion of the Scholte wave effects in the discussion but suggest adding more motivation of this part of the work at the start of section 3.

Response:

To clarify the motivation of the Scholte waves analysis, we have added the following sentences in the manuscript:

Lines 151-153

Understanding the shallow offshore structure is important because low-velocity sediments and the water column strongly affect ambient noise wavefields and surface-waves recorded by OBS stations. These effects can influence waveform characteristics and offshore earthquake monitoring.

and Lines 160-161

Characterizing these interface-guided waves helps explain the observed ambient noise correlations and the influence of shallow sediments on offshore seismic monitoring.

Additional comments:

• Abstract lines 11-13: The wording in the first sentence seems clunky maybe something like: ”The Horda Platform in the Norwegian Sea will host several CO2 storage sites that were awarded licenses. This requires a ...”

Response:
We have modified the sentence as suggested (Lines 11-13):

“The Horda Platform in the Norwegian North Sea will host several awarded CO2 storage licenses. This requires a robust understanding of background seismicity for site characterization and baseline monitoring.”

• Abstract lines 21-23: The sentence ”These events...” reads more like a results or conclusion statement and should probably be moved after the following (”Bayesian hierarchical...”) sentence. Also, are you after seismicity assessment or seismic hazard assessment. I imagine the seismic hazard assessment is part of the storage site regulatory requirements, so mentioning that the baseline seismicity

Response:

We have moved the sentence as suggested to improve the flow of the abstract. This study focuses on baseline seismicity characterization rather than a full seismic hazard assessment. We therefore revised the wording to clarify that the expanded catalog provides an improved baseline characterization of regional seismicity relevant for future monitoring of the CO2 storage site.

• Figure 1: change ”oild” to ”oil” in the legend.

Response:

We have implemented the change as suggested.

• Line 123: remove period after ”Bergen”

Response:

We have modified the sentence to improve the readability (Lines 127-128):

“As expected, the OBS stations exhibited higher noise levels than the ASK station on the western coast near Bergen, with differences of up to approximately 20 dB at 10 Hz, particularly on the horizontal channels.”

• Figure 9: the caption or a legend should clearly indicate which marker (green or red) refers to the locations using only on-land stations and all station, respectively.

Response:

• Data Resources should include the source and location fo the fault traces shown in Figure 1.

Response: We have included the source of the fault traces and the oil fields shown in Figure 1 in “Data and code availability” section:

“The Fault and oil field data are available on The Norwegian Offshore Directorate portal: https://factmaps.sodir.no/map/.”