UNDERWATER NOISE FROM WIND AT THE HIGH NORTH LOVE OCEAN OBSERVATORY

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Abstract: *The Lofoten-Vesterålen (LoVe) Cabled Ocean Observatory is located in an oceanographic, ecological, and economical hotspot off the Northern Norwegian cost. The observatory is a national research infrastructure under development by a national consortium led by the Institute of Marine Research (IMR). The first observation node of the infrastructure was launched in September 2013 and is located at 258 m depth about 15 km offshore.*

Preliminary analyses [1] using hydrophone recordings from Node 1 indicate that wind generated noise at low frequencies is significantly higher at the LoVe Observatory than in the commonly used Wenz curve. A more thorough study of wind generated noise using larger datasets from the hydrophone at Node 1 is presented here.

Hydrophone data are summarized in percentile plots to describe the variation in underwater noise. Metadata on shipping from AIS (Automatic Identification System) and metadata on wind from the Norwegian metrological institute have been used to show how much of the variation in underwater noise that may be explained by wind. Our results show that the LoVe area is a quiet area suitable to study noise from wind, and our results confirms that the wind generated noise at low frequencies is significantly higher at the LoVe Observatory than in the Wenz curve.

Keywords: *Underwater noise, ambient noise, ocean soundscape, LoVe Ocean Observatory, wind, AIS, whale vocalization*

1. INTRODUCTION

The Wenz curve [2] is established as the main reference (Fig 7.5 in [3] and Fig 8.13 in [4]) for the ocean soundscape, but it is made for deep water. The soundscape in shallow water is site dependent [5] and still a topic for research [6]. Acoustic measurements from the Lofoten-Vesterålen (LoVe) observatory are in this paper used to investigate whether the Wenz curve is representative for the LoVe area as well.

2. THE LOVE OCEAN OBSERVATORY

The LoVe Ocean Observatory [7][8] is located at 258 m depth 15 km offshore of the Northern Norwegian coast. Node 1 was launched in September 2013 by Equinor, the Norwegian Institute of Marine Research (IMR) and Metas AS. Node 2, 3, 4, 5 and 7 will be launched in 2019 by a national consortium led by IMR. Node 6 may be installed in 2020. The expansion from 1 to 7 nodes is funded through the National Infrastructure for Research program.

The main objective of the infrastructure is to further develop the knowledge base of the physical, chemical, and biological environment in this ecologically important area. Each node will host a suite of oceanographic, biological and chemical sensors, including hydrophones which continuously monitor the marine soundscape. An analysis of the hydrophone data from Node 1 is presented here.

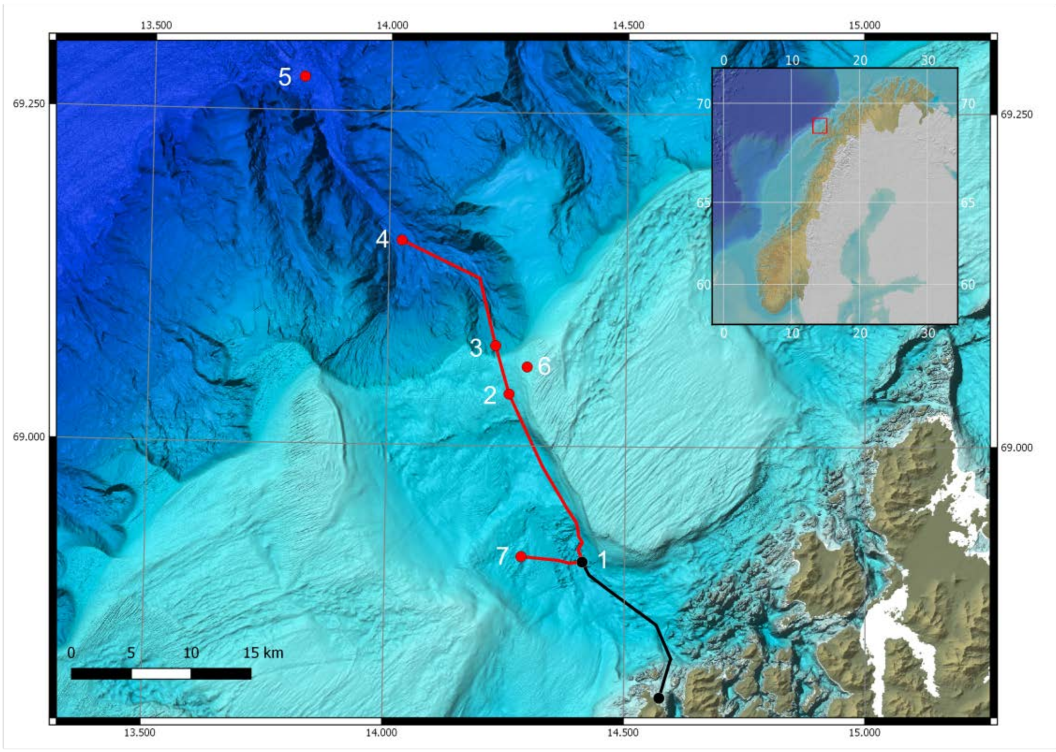

Fig.1: Localization of the LoVe Ocean Observatory and its underwater nodes.

3. METHOD

Underwater noise from wind is studied in samples with ship far from the hydrophone (Range > 30 km). The wind data used is from Nora10 (NOrwegian ReAnalysis with 10 km grid) [9][10] from the Norwegian Meteorological Institute. The wind data is a re-analysis of historical weather based on a model, but strongly constrained by available observations. An example of wind speed estimated at the LoVe Observatory is shown in Fig 2.

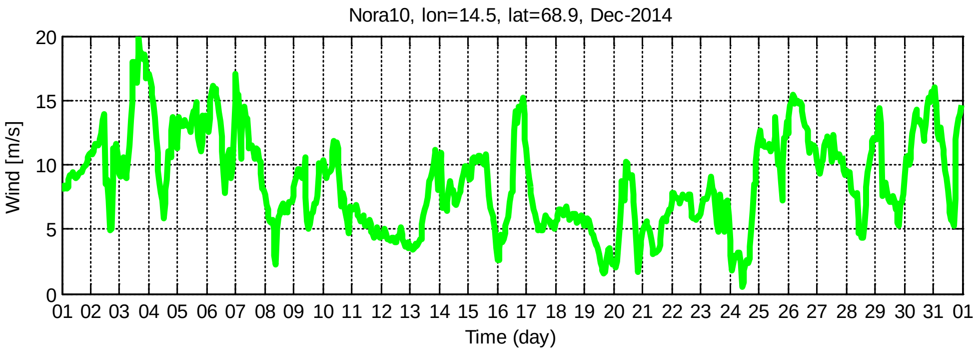

Fig.2: Wind at the LoVe Observatory (Nora10 data for Dec 2014)

AIS-information from Kystverket [11] on shipping around the LoVe Observatory has been used to find time periods without significant noise from shipping. The two first plots in Fig 3 show shipping information in two of the time periods used to study underwater noise from wind. Periods with AIS ship closer than 30 km from the hydrophone are removed in the study of ambient noise from wind.

The last plot in Fig 3 shows the shipping density in December 2014, which was the first complete month with high quality hydrophone data from the LoVe Observatory. The plot shows that the main traffic lane along Norway, i.e. the shipping lane for large ships as tankers and 200 m long cargo ship, has CPA (Closest Point of Approach) around 55 km from the LoVe Observatory, while a traffic lane for smaller Cargo ships has CPA close to the hydrophone.

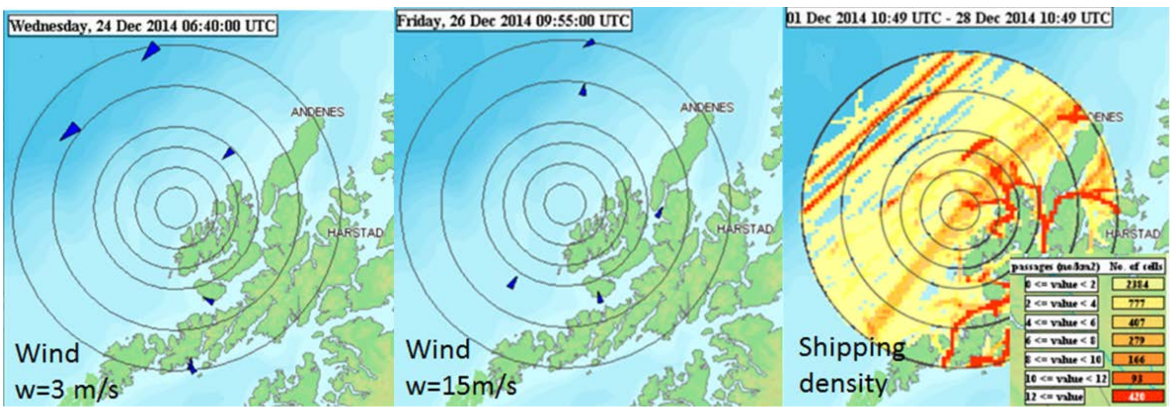

Fig.3: AIS plot from the LoVe (Lofoten Vesterålen) area. The LoVe-hydrophone is located at the center of the circles. The circles have radius of 10, 20, 30, 40, 60 and 80 km.

The hydrophone at the LoVe Observatory has recorded high quality data in the frequency band between 10 Hz and 16 kHz. The recordings at higher frequencies have not been used in this study, because they are disturbed by noise from the echosounders at the LoVe Observatory. The hydrophone data has first been processed as specified in the EU-project JOMOPANS [12], i.e. averaged over 1/3 octave frequency band and sampled every second. The results have then been resampled from 1s to 300s resolution by taking the median over 300 1s data to improve the estimates of the ambient noise from wind. The median is used to avoid or at least reduce the effect of biological and system noise transients.

Curves of ambient noise as function of frequency for a given wind speed are calculated as the median over all high quality samples in a month satisfying:

1. Wind within: Wind speed studied +/- 2.5 m/s
2. No ship (with AIS) closer than 30 km

The sensitivity of the hydrophone (SB35 ETH from Ocean Sonic) is -171 dB re 1 V/µPa with pre-amp [13]. This is an average value for all the frequencies and ± 3 dB must therefore be added to the spectrum levels reported here. The peak measured signal of the hydrophone is 175 dB re 1 µPa

4. RESULTS

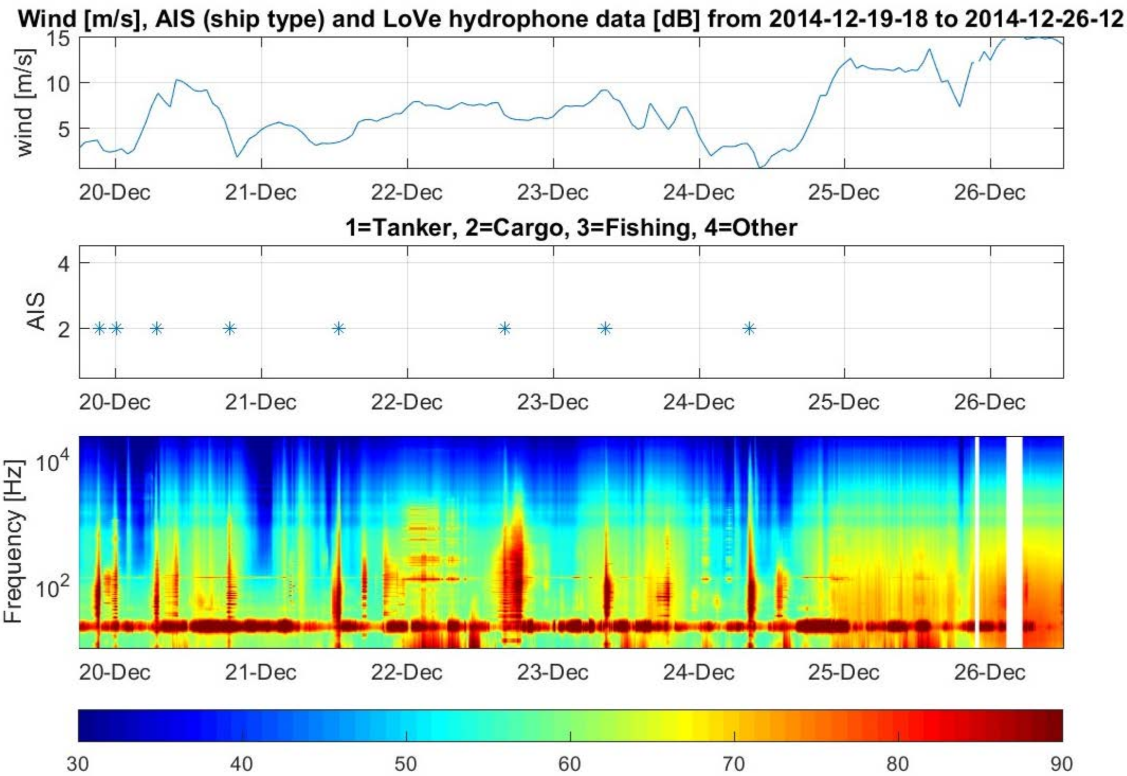

Fig.4: Underwater sound (lower), Shipping information from AIS (middle) and wind (upper) for a week in Dec 2014. Ship closer than 5 km to the LoVe Observatory is shown in the AIS plot. The frequency axis in the lower plot is logarithmic, and the color in dB re 1 µPa²/ Hz.

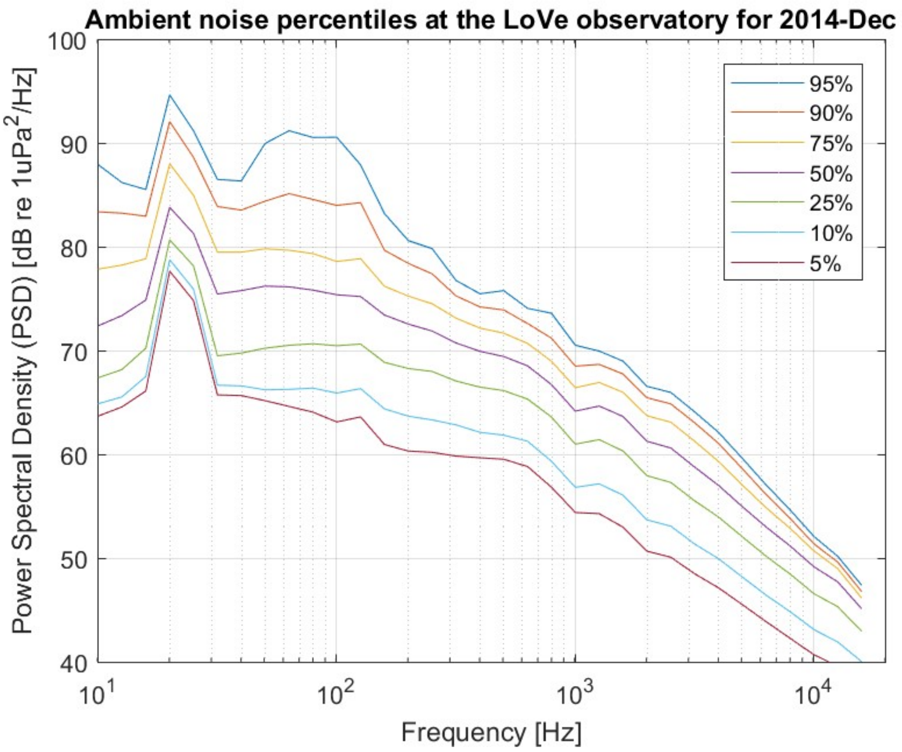

Fig.5: Percentile plots of underwater sound as function of frequency for December 2014.

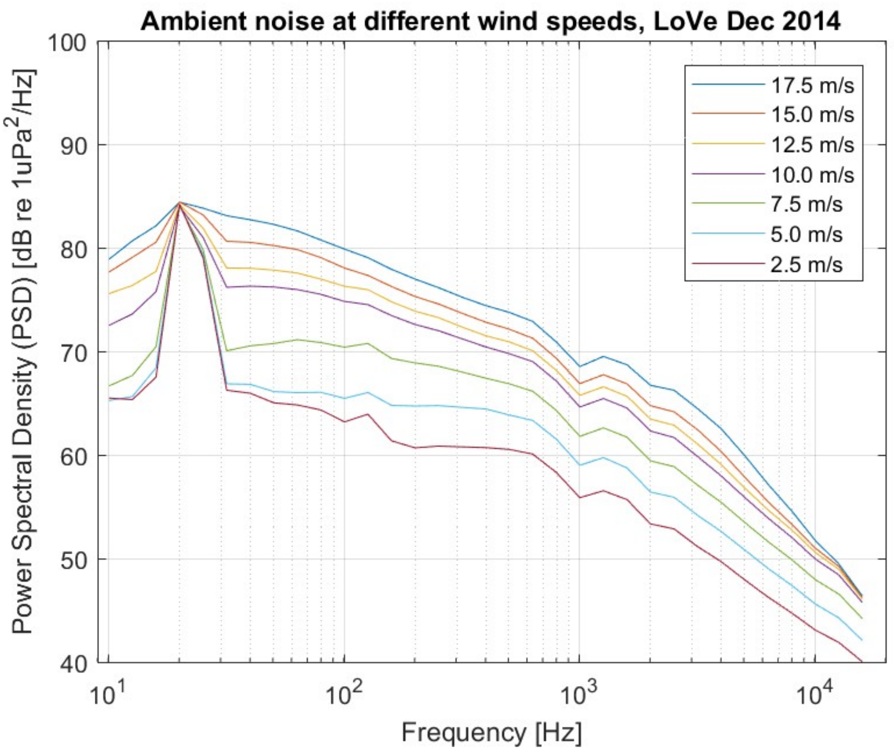

Fig.6: Underwater sound as function of frequency for different wind speeds.

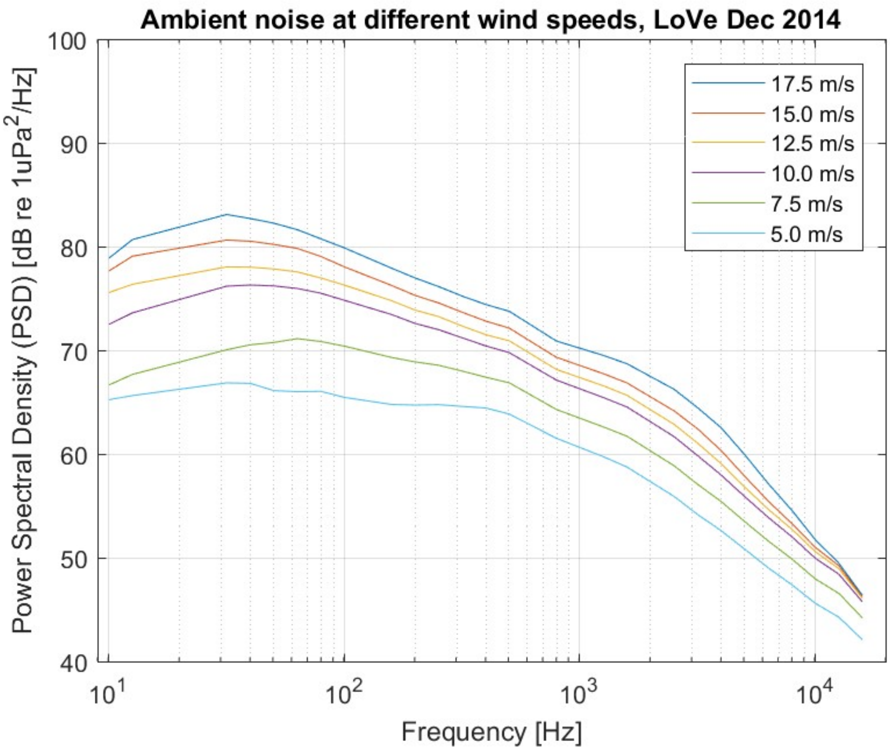

Fig 7: Underwater sound as function of frequency for different wind speeds after removing contributions from Fin whale and system resonances around 1000 Hz.

Fig 4 shows an example of the quality of the LoVe hydrophone data together with metadata on wind and shipping. A higher frequency resolution than 1/3 Octave frequency band has been used in this plot to better illustrate the quality of the data. The plots show that the ambient noise is correlated with wind, and the LoVe data is therefore useful for studying underwater noise from wind, but the plot also illustrate that periods with vessels close to the hydrophone must be removed in the wind study. More detailed plots confirm that periods with ship closer than 30 km to the hydrophone must be removed.

The variation in the ambient noise data recorded in December 2014 is summarized in a percentile plot in Fig 5, while the remaining variation after removing recordings with vessels close to the hydrophone are shown as a function of wind speed in Fig 6.

The Fin whale is known to vocalize around 20 Hz, and the strong peak between 17 and 28 Hz shown in Fig 5 and 6 is concluded to be Fin whale. The Fin whale frequencies are therefore removed in Fig 7. Some samples around 1000 Hz are also removed, because they are disturbed by system resonances.

5. DISCUSSION/ CONCLUSION

Fig 5 shows that the underwater noise is up to 27 dB higher in the 5% loudest periods compared to the 5% most quiet periods in December 2014, while Fig 6 shows that much of the variation in ambient noise may be explained by variation in wind speed. An increase in wind speed from 2.5 m/s to 17.5 m/s gives an increase in ambient noise of up to 17 dB.

The largest variation seen in the percentile plot in Fig 5 is between 50 and 100 Hz, which may be explained by shipping. Biological sounds are also significant. The Fin whale is known to vocalize at low frequencies, and the strong peak between 17 and 28 Hz shown in Fig 5 and 6 is concluded to be Fin whale. The Fin whale frequencies are therefore removed in Fig 7. Frequencies around 1000 Hz is removed as well, because they are disturbed by system resonances.

Fig 7 is concluded to be the final estimate of wind driven ambient noise at the LoVe observatory in December 2014. An interesting observation in Fig. 7 is that the ambient noise at high frequencies (20 kHz), do not increase with wind speed in the same way as for lower frequencies. The effect may be because of a layer with attenuating bubbles made by wind and waves.

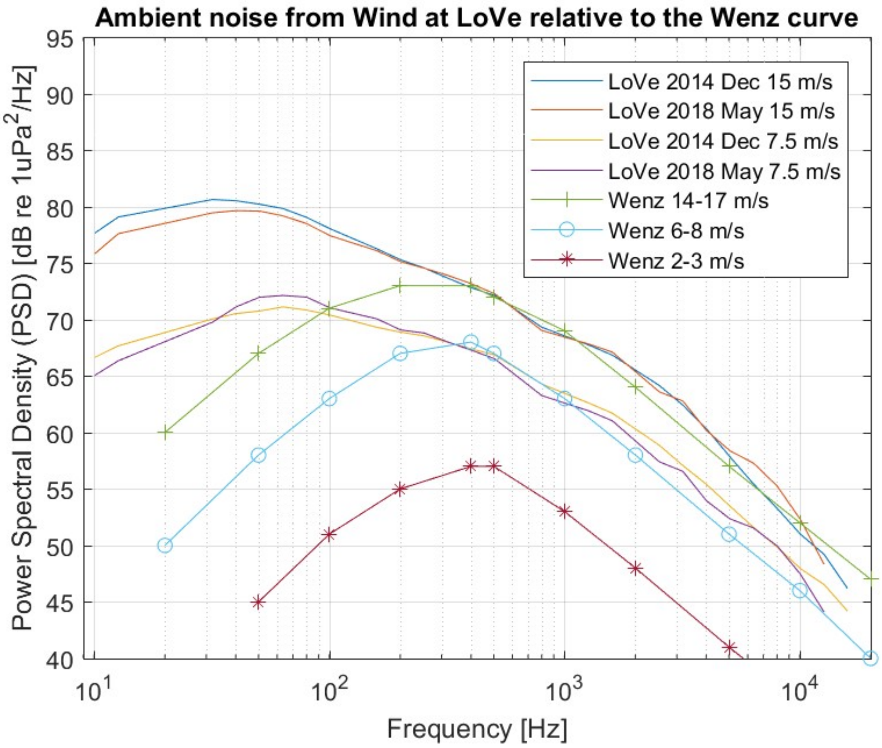

Fig 8: Underwater sound as function of wind at the LoVe Observatory compared to the deep water Wenz curve.

The main purpose of the work in this paper has been to compare the soundscape at the LoVe Observatory with the Wenz curve. The Wenz curve for 2-3 m/s, 6-8 m/s and 14-17 m/s wind is plotted in Fig 8. It is adapted from Fig 7.5 in [3] and based on Wenz's article from 1962 [2]. The LoVe wind curves plotted in Fig 8 are similar to the Wenz curve for frequencies higher than 400 Hz, but the LoVe wind curves show much higher ambient noise at frequencies below 400 Hz.

The results from the LoVe Observatory are more similar to measurements from shallow water [5], and we conclude that the data from the LoVe hydrophone at 258 m depth must be handled as shallow water data, not deep water data.

The results presented in Fig 4-7 shows data from December 2014 only, but the same calculations have been done for 1-27th May 2018 as well. Fig 8 shows that the ambient noise in December 2014 and May 2018 are almost equal for 7.5 m/s wind and 15 m/s wind, which indicate that the ambient noise from wind is independent of month.

The estimated curves for ambient noise at 2.5 m/s wind shows however a difference between the curves from December 2014 and May 2018. It is assumed that the ambient noise level at 2.5 m/s wind is so low that the samples are disturbed by shipping at larger distances than 30 km and biological sounds. The curve for 2.5 m/s wind in Fig 6 is therefore assumed to show too high ambient noise level and it is therefore removed from Fig 7 and 8. A more detailed and more manual study has to be done on the ambient noise curve for 2.5 m/s wind.

6. ACKNOWLEDGEMENTS

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[13] **Metas AS,** *Technical Information LoVe Sensors installed.*
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