ARCTIC
VOL. 73, NO. 2 (JUNE 2020) P. 386–392
https://doi.org/10.14430/arctic70499

Underwater Ambient Noise in Kongsfjorden, Spitsbergen, during the Summers of 2015 and 2016

Muthuraj Ashokan,[1,2] Ganesan Latha[1] and Ayyadurai Thirunavukkarasu[1]

(*Received 15 February 2019; accepted in revised form 14 January 2020*)

ABSTRACT. Underwater ambient noise was measured in Kongsfjorden, Svalbard, during the summers of 2015 and 2016 to understand the contribution of iceberg bubbling, iceberg calving, and shipping noise to the acoustic environment of the fjord. Comparison of the ambient noise data for the months of August, September, and October showed that average noise levels were similar, although the average noise level for 2015 was ~9 dB higher than in 2016 because of higher shipping noise. Maximum ambient noise was produced at frequencies less than 10 kHz during both summers. Spectrograms of iceberg calving noise showed that it occurred in the frequency below 500 Hz. Shipping noise was seen in the band below 600 Hz, and iceberg bubbling noise was detected in the band above 400 Hz. Instrument noise was observed in the frequency 400 Hz. It is clear that ice breaking and shipping contribute substantially to ambient noise in Kongsfjorden.

Key words: Arctic; IndARC; noise; summer; Kongsfjorden; Iceberg; bubbling; melting; shipping

RÉSUMÉ. Au cours des étés 2015 et 2016, le bruit ambiant sous-marin a été mesuré à Kongsfjorden, dans le Svalbard, dans le but de comprendre la contribution du pétillement des icebergs, du vêlage des icebergs et du bruit émanant du transport maritime à l’environnement acoustique du fjord. La comparaison des données du bruit ambiant pour les mois d’août, de septembre et d’octobre a permis de constater que les niveaux de bruit moyens étaient semblables, bien que le niveau de bruit moyen de 2015 était supérieur dans une mesure de ~9 dB à celui de 2016 en raison du niveau de bruit plus élevé émanant du transport maritime. Le bruit ambiant maximal a été produit à des fréquences de moins de 10 kHz pendant les deux étés. Pour ce qui est du bruit du vêlage des icebergs, les spectrogrammes ont permis de démontrer qu’il s’établissait à une fréquence inférieure à 500 Hz. Le bruit du transport maritime se trouvait dans la bande inférieure à 600 Hz, tandis que celui du pétillement des icebergs se situait dans la bande supérieure à 400 Hz. Le bruit des appareillages a été observé dans la fréquence de 400 Hz. Il est clair que le déglaçage et le transport maritime jouent un grand rôle dans le bruit ambiant à Kongsfjorden.

Mots clés : Arctique; IndARC; bruit; été; Kongsfjorden; iceberg; pétillement; fonte; transport maritime

Traduit pour la revue *Arctic* par Nicole Giguère.

INTRODUCTION

Acoustical oceanography methods can be used effectively to study the ambient noise in glacierized fjords and provide insight into glacier ice variations (e.g., Pettit, 2012; Glowacki et al., 2015; Pettit et al., 2015a). The main mechanism by which melting glacial ice produces underwater noise was first acknowledged by Urick (1971) who discovered that forced bubbles of air escaping from the ice yielded a variety of noise signatures. The intensity of underwater ambient noise in glacial fjords depends not only on the number and spectral signatures of iceberg calving and melting, but also on the circulation of icebergs in space and the propagation features of the fjord itself. Pettit et al. (2015b) characterized the ambient noise surrounding fjords and found that average ambient noise levels are louder near the fjords. The underwater sounds associated with glacier melting events in the fjords were explained by Tegowski et al. (2011) who observed that noise levels vary between the fjords because of geophysical phenomena such as earthquakes and ice caps. Keogh and Blondel (2009) correlated and explained ambient noise measurements in Arctic fjords using tank experiments performed in the summer of 2007. Time-series ocean ambient noise measurements in the shallow waters along the east and west coasts of India have been acquired using an autonomous noise measurement system developed by the National Institute of Ocean Technology, Chennai, India; this enhanced system has been deployed in the Arctic (Ashokan et al., 2015, 2016).

BACKGROUND

Hornsund and Kongsfjorden are located on Spitsbergen, an island in the Svalbard Archipelago, Arctic Ocean (Cottier et al., 2010; Promińska et al., 2017). The ambient noise near Hornsund has been extensively studied (Glowacki et al., 2016), but noise research near Kongsfjorden is

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[1] Ocean Acoustics Group, National Institute of Ocean Technology, Ministry of Earth Sciences, Chennai, India 600100
[2] Corresponding author: ashokan@niot.re.in

very limited. Kongsfjorden is a thin fjord, dominated by Atlantic water from West Spitsbergen (Svendsen et al., 2002; Cottier et al., 2010). Hence, a seasonal variation in the time of ice breakup is normal in this location. Wiencke and Hop (2016) found that a reduction in sea ice in this location has occurred rapidly in recent years because of global warming. Promińska et al. (2017) reported that Kongsfjorden undergoes more warming with rapid temperature changes than Hornsund. Feng and Hu (2008) and Goswami et al. (2006) showed that variabilities in the Indian summer monsoon rainfall is physically linked with the North Atlantic Oscillation. To monitor the Arctic Ocean parameters continuously for prolonged periods, a multi-sensor mooring with an ambient noise measurement system was deployed in Kongsfjorden (Venkatesan et al., 2016). The extent of sea ice is the lowest in the Arctic during summer; thus, only data from the summer period have been analysed (Sanjana et al., 2018).

Experimental setup and location

The National Institute of Ocean Technology (NIOT), jointly with National Centre for Polar and Ocean Research (NCPOR), Ministry of Earth Sciences, Government of India, has installed a mooring system in Kongsfjorden, called 'IndArc' (Fig. 1) (Venkatesan et al., 2016; Sanjana et al., 2018). The IndArc mooring system measures ambient noise using a hydrophone and a data acquisition system. In 2015, the ambient noise system acquired data at a sampling rate of 50 kHz for a duration of 60 sec every three hours. In 2016, the data acquisition was increased to 180 sec every hour. We analyzed ambient noise records during summer (August – October) in the years 2015 and 2016. The raw data sets were stored in the external hard disk in ASCII format. The hydrophone was positioned at a depth of 30 m from the sea surface where the mooring depth is 190 m. The power pack for the ambient noise measurement system was designed to collect data for eight months. The hydrophone preamplifier gain is 20 dB and the sensitivity is – 185 dB re 1V/uPa. The sensor was tested and calibrated at the Underwater Acoustic Test Facility of NIOT, which is accredited by the National Accreditation Board for Testing and Calibration Laboratories in India. The IndArc moored system consists of various sensors such as a CTD to measure conductivity, temperature, and depth, an acoustic Doppler current profiler (ADCP), a sensor for photosynthetically active radiation (PAR), and a submersible underwater nitrate analyser (SUNA). The primary objective of acoustic observation in the Arctic is to understand glacier melting and the Arctic acoustic environment. The IndArc system was deployed from the Norwegian Polar Institute's research vessel RV *Lance*. The moored system was retrieved after the measurement period and each data set was downloaded and analysed separately. Acoustic data were converted to a time series of acoustic pressure. Welch's power spectral density method was used for estimating the ambient noise levels. The Hamming window and 4096-point FFT with 50% overlap (~25 Hz bins) technique was employed for these estimates.

METHODS

The instruments such as PAR and SUNA that are connected in the mooring line create noise, which is predominant at the experiment site. The PAR sensor measures the photosynthetic photon flux density (PPFD) and the SUNA sensor measures the nitrate in the mooring location. Each device has a self-cleaning apparatus to clean the exterior of the sensor. Once this apparatus starts to clean the sensor, it makes noise, which is also recorded by the noise measurement system along with the ambient noise. Figure 2a and 2b show that the instrument noise falls in the frequency band 250 – 450 Hz, which is present throughout the sampling time. In order to analyse the iceberg bubbling noise, instrument noise needs to be filtered out and was eliminated by applying a Butterworth filter algorithm using MATLAB to the time series raw data. This technique was applied to all the underwater ambient noise data sets to filter out the instrument noise frequencies from the information on iceberg noise and shipping noise. The ASCII formatted noise data sets were then converted to *.wav files, which were analysed by hearing aids. By comparing the spectrograms and power spectra with *.wav files, we found that the sound emanates from the escape of air that remains trapped in the icebergs.

Wind speed and air temperature data sets for the moored location were obtained from the Norwegian Meteorological Institute. These data sets were collected at a sampling period of every 6 hours starting from 1 August 2016 at 0000 UTC to 31 October 2016 at 1800 UTC (Fig. 3a, b).

RESULTS AND DISCUSSION

A maximum wind speed of 14.8 m/s was observed on 27 October 2016 at 1200 UTC. High wind speed events have been observed during the period September to October (Fig. 3a). A peak air temperature of 9.3˚C was observed on 20 August 2016 at 1200 UTC and a minimum air temperature of −5.8˚C was observed on 15 October 2016 at 1200 UTC (Fig. 3b).

The wind speed events are correlated with the ambient noise acquisition time. To avoid the wind confounding iceberg sounds, noise data sets having wind speed below 3 m/s (Ashokan et al., 2015) alone are considered for the analysis of iceberg melting sounds. Spectrograms of iceberg melting noise are shown in Figure 4a and 4b. The spectral shape detected (Fig. 4a and 4b) in the frequency band above 400 Hz describes the sound of melting ice that occurred near the IndArc mooring system (Blondel et al., 2013; Lee et al., 2013). The spectograms show that the noise level is higher than 90 dB re 1 μPa2/Hz in the frequency band 0.5 – 2 kHz. (Fig. 4a, b). The noise spectrum observed

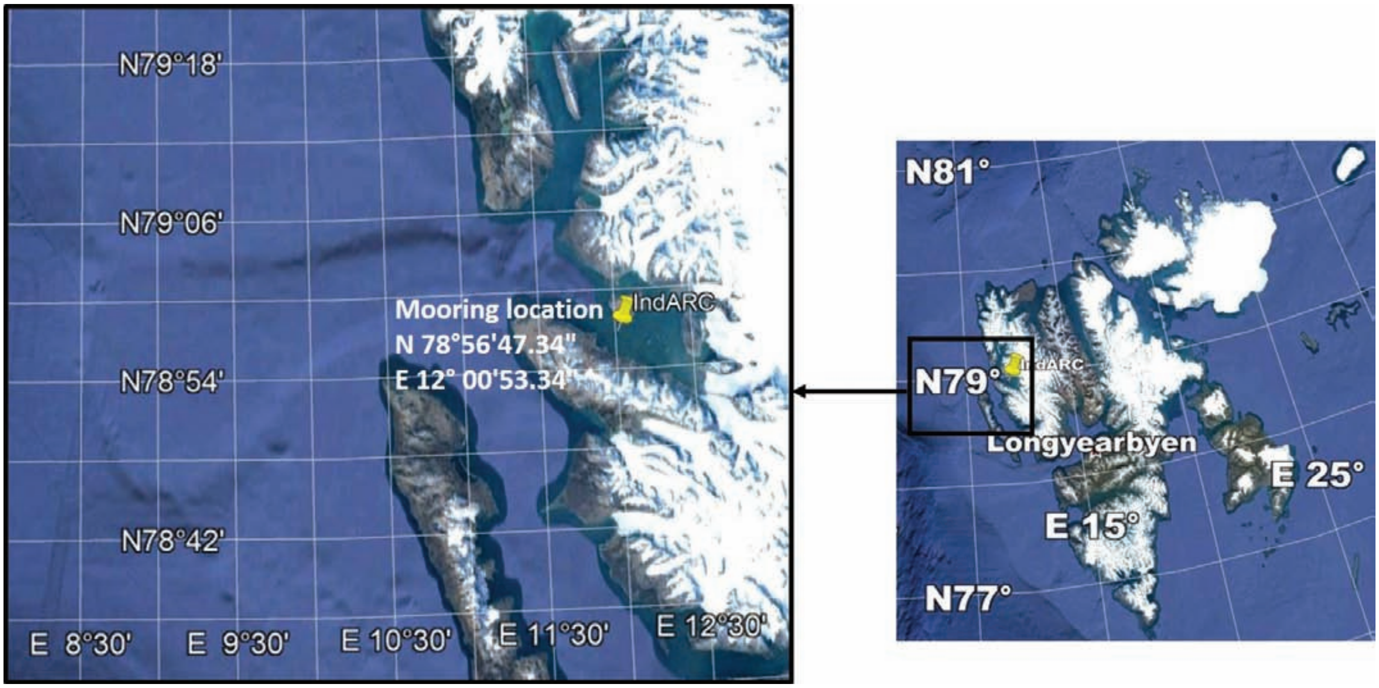

FIG. 1. Mooring location of the underwater ambient noise measurement system in Kongsfjorden, Spitsbergen, Svalbard. (Source: Google Earth.)

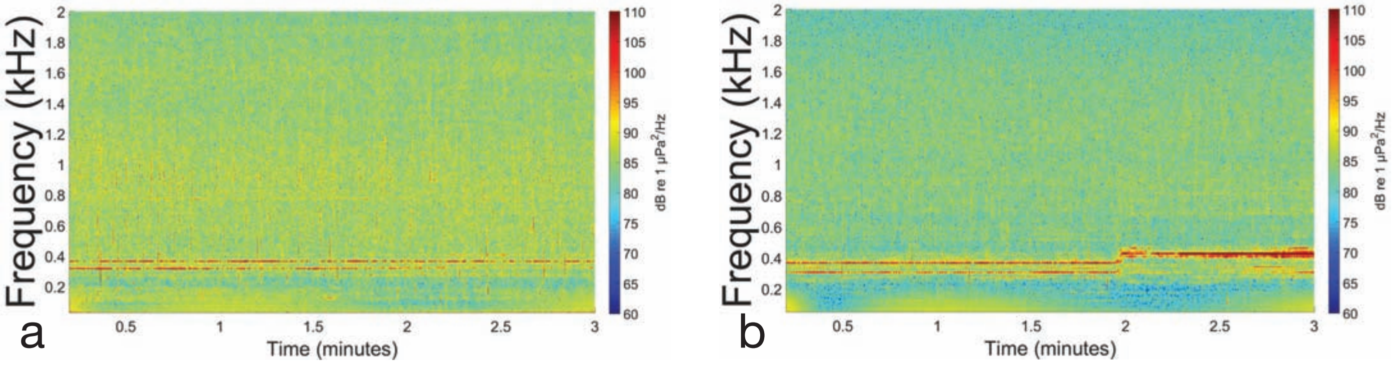

FIG. 2. Spectrograms of the instrument noise data (seen in the frequency 0.3–0.5 kHz) from a) 3 August 2016 at 1121 UTC, and b) from 6 August 2016 at 0529 UTC.

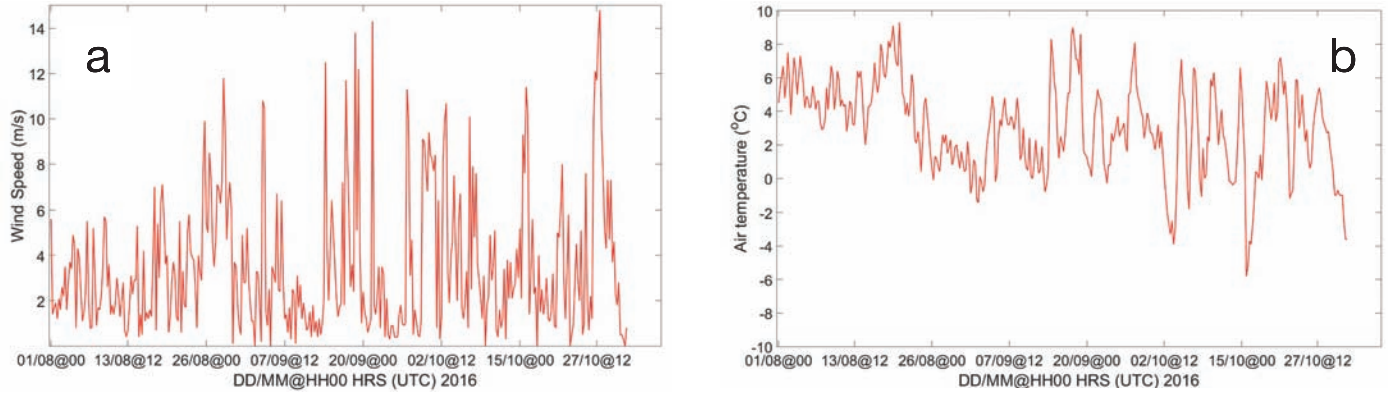

FIG. 3. a) Wind speed events for the period 1 August 2016 to 31 October 2016, and b) Air temperature recordings for the same period.

in the frequency band 0.5–2 kHz is due to the escape of air that is trapped in the glacier ice, which generates bubbles in the water column when the ice melts. Noise levels in glacial fjords during the summer period (acquisition period) are above 90 dB re 1 μPa2/Hz (Fig. 4a, b). Figure 4c clearly shows that the melting sound of icebergs is the dominating

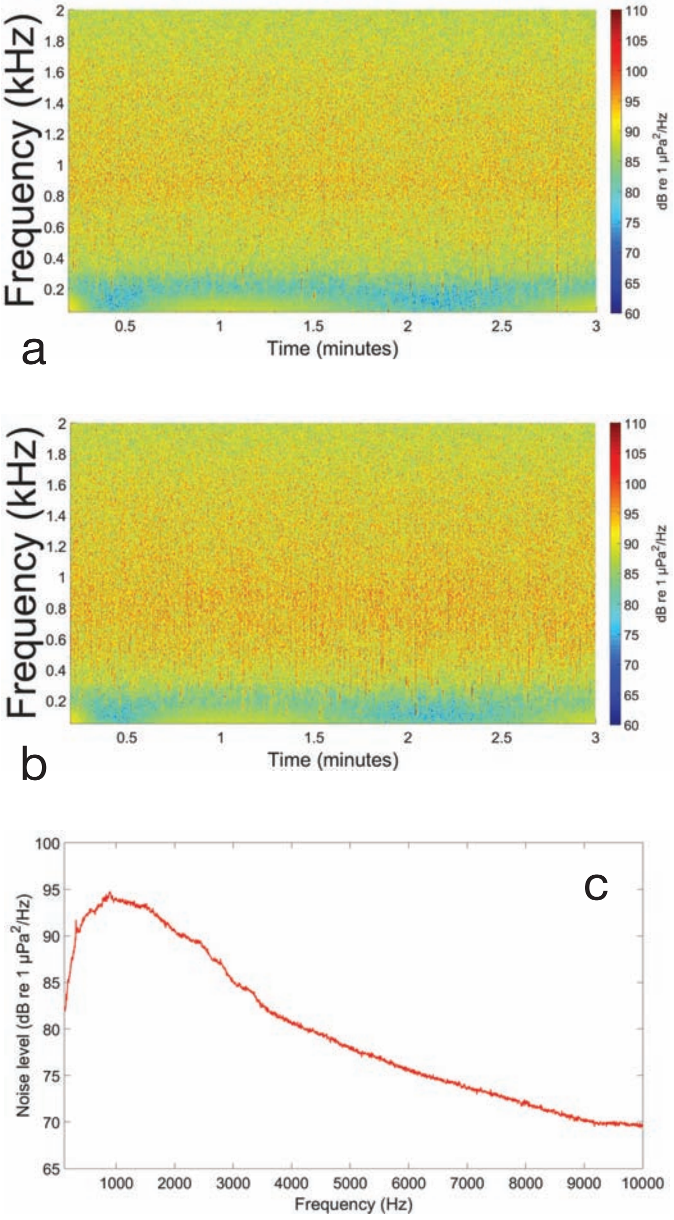

FIG. 4. Spectrograms of the iceberg melting noise (seen in the frequency > 0.5 kHz) from a) 19 August 2016 at 1208 UTC, and b) from 26 September 2016 at 1701 UTC. c) Power spectrum of the iceberg melting noise at wind speeds below 3 m/s and air temperature of 9.1˚C on 19 August 2016 at 1208 UTC.

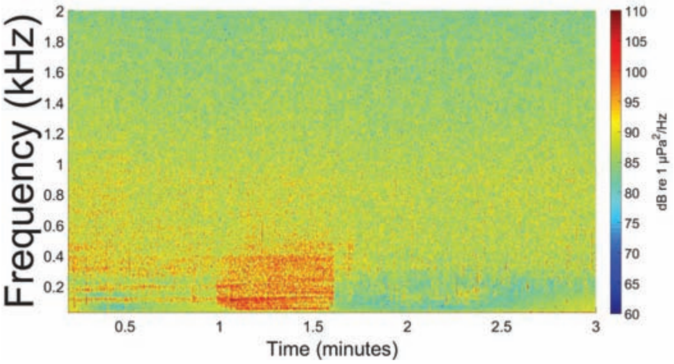

FIG. 5. Spectrogram of the iceberg calving noise (seen in the frequency < 0.5 kHz between the time 1 – 1.6 min) on 3 August 2016 at 2022 UTC.

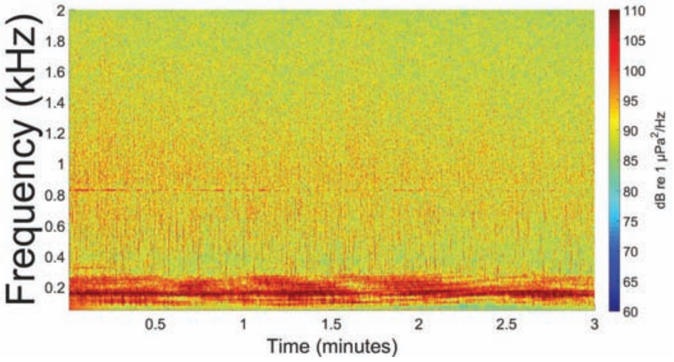

FIG. 6. Spectrogram of the shipping noise (seen in the frequency < 0.3 kHz throughout the acquisition period) and iceberg melting noise (seen in the frequency > 0.5 kHz) on 3 August 2016 at 1721 UTC.

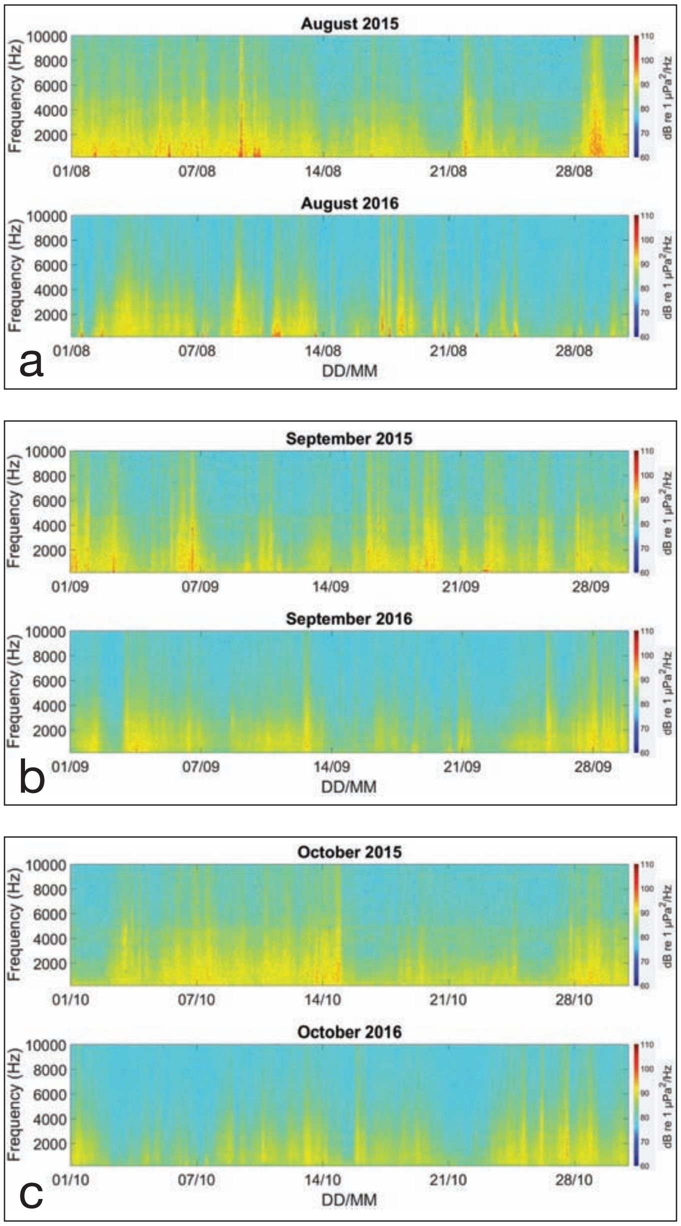

FIG. 7. Comparative spectrograms for a) August 2015 and August 2016, b) September 2015 and September 2016, and c) October 2015 and October 2016.

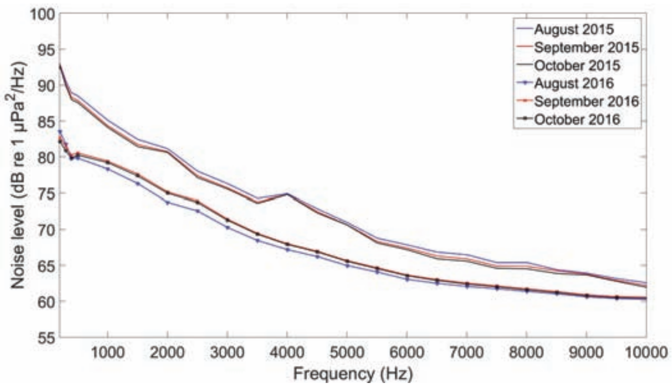

FIG. 8. Average power spectral density estimations for August, September, and October 2015 and 2016.

source of noise, since the wind speed below 3 m/s does not contribute to ambient noise. Wind speed induces the surface wave breaking noise only beyond 3 m/s (Ashokan et al., 2015).

A small iceberg calving event was captured by the ambient noise measurement system (Fig. 5) on 3 August 2016 at 2022 UTC. The entire ice calving noise falls in the frequency band below 500 Hz, and the ambient noise level increases by 10 – 20 dB re 1 µPa2/Hz from the usual values (Rignot et al., 2010; Tegowski et al., 2011). The frequency above 500 Hz is totally dominated by the iceberg melting noise, since the iceberg calving event and the iceberg melting sound occur simultaneously.

Shipping is a core source of low-frequency noise in the ocean (Jalkanen et al., 2018). A propeller-driven ship has several noise sources, however, underwater ship noise mainly emerges from propeller cavitation. The propeller is the highest noise source, creating high noise levels at frequencies below 400 Hz (Mustonen et al., 2019). At frequencies below 400 Hz, ambient noise levels show an increase of 15 – 20 dB re 1 µPa2/Hz because of distant shipping (Bazile Kinda et al., 2017). During the summer period, the experiment site is highly occupied by the tourist vessels, which increase the ambient noise levels (Sanjana et al., 2018).

The comparison study of ambient noise levels for August, September, and October in 2015 and 2016 considered all three-hour records in the summers of 2015 and 2016, though 2016 has an hourly record (Fig. 7a – c). Average power spectral density estimations for August, September, and October for 2015 and 2016 are shown in Figure 8, and the noise values (dB re 1 µPa2/Hz) are shown in Table 1. Average noise levels during August, September, and October are nearly the same for both 2015 and 2016 (Fig. 8; Table 1). The average noise level for 2015 is ~9 dB higher than the level during 2016. This difference is due to the high shipping noise in the order of 105 dB observed in many records in 2015 (Fig. 7a – c). During the end of summer and the beginning of winter, shipping activities and ice cracking events lessen; hence, the noise levels are observed to be at a minimum in October (Fig. 7c). Ambient noise levels are higher in August 2015, predominantly because of shipping, ice calving, and ice melting. The experimental location of Kongsfjorden is highly influenced by these sources during the peak summer period which results in the maximum ambient noise occurring in August.

TABLE 1. Average power spectral density estimations for August, September, and October 2015 and 2016.

		August 2015	September 2015	October 2015	August 2016	September 2016	October 2016
Sl. no.	Frequency (Hz)	Noise level (dB re 1 µPa2/Hz)					
1	200	93	93	93	84	83	82
2	300	91	90	90	82	81	81
3	400	89	88	88	80	80	80
4	500	89	88	88	80	81	80
5	1000	85	84	84	78	79	79
6	1500	82	82	81	76	78	77
7	2000	81	81	81	74	75	75
8	2500	78	77	77	73	74	74
9	3000	76	76	76	70	71	71
10	3500	74	74	74	68	69	69
11	4000	75	75	75	67	68	68
12	4500	73	72	72	66	67	67
13	5000	71	71	71	65	66	66
14	5500	69	68	68	64	65	65
15	6000	68	67	67	63	64	64[1]
16	6500	67	66	66	63	63	63
17	7000	66	66	66	62	63	62
18	7500	65	65	65	62	62	62
19	8000	65	65	65	61	62	62
20	8500	64	64	64	61	61	61
21	9000	64	64	64	61	61	61
22	9500	63	63	63	60	61	61
23	10000	63	62	62	60	61	60

[1] glacierized fjord

CONCLUSIONS

Analysis of the ocean ambient noise data sets in Kongsfjorden, Arctic Ocean, during the summer of 2015 and 2016 showed that the noise in the fjord is mainly caused by iceberg bubbling, iceberg calving, and shipping during the summer period. Wind speed and air temperature records have been correlated with the measured ambient noise. The noise level in Kongsfjorden varies over 20 dB within the frequency range below 10 kHz. In August 2015, the noise levels increased by 20 dB from the background noise. Continuous measurements of ambient noise in the Arctic will enable further understanding of the Arctic acoustic environment and will be helpful in climate change studies.

ACKNOWLEDGEMENTS

The authors thank the director of the National Institute of Ocean Technology for his encouragement in carrying out this research work. The authors express sincere thanks to the field team of Ocean Observation System, NIOT, for their support in the operations of the system in Arctic. Special thanks to NCPOR team, the Norwegian Polar Institute research team, and the cruise team of the vessel RV *Lance* for supporting the deployment and retrieval activities. The authors thank the Ocean Acoustics team for their support in testing and calibration of sensors. The authors are immensely thankful to the Ministry of Earth Sciences for funding this project.

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