Analysis of rain noise in shallow waters of Bay of Bengal during cyclonic storm

JAL

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Received 14 October 2013; revised 11 November 2013

Present study consist the rain noise analysis during JAL cyclone. Ocean ambient noise time series data were measured in shallow water areas of Bay of Bengal at an ocean depth of 30m using an autonomous ambient noise measuring system consisting of vertical array of hydrophones with a data acquisition system placed in mid water column. Hydrophones were placed at a depth of 15m and the data from the first element in the array (from the sea surface) were used for analysis. The noise data sets pertaining to the rain events during JAL cyclone were taken for the analysis of rain noise and used for estimating the rain fall parameters such as frequency, drop size and number of drops. Validation of the estimated rain fall events has been carried out utilizing data from Indian Metrological Department (IMD) Chennai.

[Keywords: underwater acoustics, ocean observation, weather, rain acoustics, cyclone]

Introduction

In oceanic region the estimation of the rainfall parameters are important, and needs special arrangements in comparison with the stable platforms employed to the commercial land-based systems. Employment of such technique for ocean applications is extremely difficult. Rain produces a loud and unique underwater sound that can be used to detect and quantify oceanic rainfall. Specifically at the time of cyclonic events, sound caused by rain is more which was discussed in this paper. The technique to acquire the rain noise in underwater applications requires use of hydrophones and data logger electronics.

Rain noise varies with many parameters such as frequency, falling rate, drop sizes, number of drops, impact velocity, impact angle and rain drop-ocean surface impact & interaction. There are various mechanisms by which rain can generate underwater sound – the striking of raindrops on the sea-surface, the sound of single bubbles produced by "small-size" raindrops and the generation of splash associated bubbles caused by "large" raindrops. Rain parameter estimation is a challenging process when the addition of wind noise arises, which not only generates its own sound, but also affects the sound that produced by rain. Light rain (drizzling) falls in the frequency band of 14-15kHz and the rain drop diameter is less than 1.1 mm. Heavy rainfall noise occurs in the frequency band less than 10 kHz and the rain drop diameter is greater than 2.2 mm. The types of rain drops and it sizes are illustrated in the Table 1. In NIOT, extensive studies have been carried out on wind generated noise for different locations in Indian oceans. Additionally, studies on noise due to rainfall have been initiated recently. Rain noise parameters at the time of cyclone or storm environments have not been carried out so far in Indian shallow waters. Rain noise spectrum during JAL cyclone during the October, 2010, has been analysed from time series measurements. This paper presents the work done for estimating the rainfall parameters like frequency, drop size and number of drops during JAL cyclone period.

Materials and Methods

Ocean ambient noise measurements in the Indian shallow waters have received much attention and many field experiments have been conducted in the past one decade. The rainfall rate and wind would be more at the time of cyclone or storm. The splash of the rain drop depends on the drop size and there from the production of acoustic signatures begin. The small rain drops having diameter greater than 0.8 mm and less than 1.2 mm produce sound.
Table 1—Types of rain drops

<table>
<thead>
<tr>
<th>Rain drop</th>
<th>Diameter range</th>
<th>Detectable</th>
<th>Frequency range</th>
<th>Type of rain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minuscule</td>
<td>D &lt;=0.8mm</td>
<td>Un detectable</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Small</td>
<td>0.8mm &lt; D &lt;= 1.1mm</td>
<td>Detectable</td>
<td>15kHz</td>
<td>Drizzling (Light rain)</td>
</tr>
<tr>
<td>Mid-Size</td>
<td>1.1mm &lt; D &lt;= 2.2mm</td>
<td>Un detectable</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Large</td>
<td>D &gt; 2.2mm</td>
<td>Detectable</td>
<td>&lt; 10kHz</td>
<td>Heavy rain</td>
</tr>
</tbody>
</table>

These small rain drops exist in all kinds of rain fall including light rain called drizzling, which has the frequency range around 14 kHz and heavy rain called thunder storm, which falls at the frequency band of less than 10 kHz (Table 1) 3-8. In this work, heavy rain fall noise in underwater was acquired using 12 elements vertical linear array hydrophone.

At any given instant, the local pressure in the hydrophone at measurement site can be stated as the sum of all acoustic signature sources surrounded on the hydrophone,

$$P_a = P_r + P_w + P_{ss} + P_{ml} + P_{st} + P_{other}$$

Where r, w, ss, ml, and st are denotes rain, wind, sea state, marine life and ship traffic noise respectively7.

The individual contribution of the acoustic pressure on hydrophone produced by the various sources cannot be separated in real time acquisition. At the same time, the frequency spectrum [SPL (f)] of these acoustic pressures can be distinguished, such as Pw (only wind) & Pr (only rain). The receiving sensitivity of the hydrophone is -168 dB rel 1VμPa. The preamplifier system gain is fitted about 26 dB rel 1VμPa. The frequency spectrum of the heavy rain fall noise during JAL cyclone period is analyzed and the rain fall parameters are estimated.

**Instrumentation Setup**

A long mooring experiment for the acquisition of underwater ambient noise in shallow waters off the West coast of India was conducted from 27 October 2010 to 02 December 2010 for acquiring continuous passive acoustic measurements which recorded noise due to JAL cyclone also. NIOT has indigenously developed an autonomous ambient noise sub surface system which consists of a 12 element vertical linear array having omni-directional hydrophones with associated data acquisition modules and battery pack as an enclosure, along with subsea floats and surface marker buoy in the mooring line. Hydrophones with frequency range 100Hz to 10 kHz have been used.

Hence, all the rain noise data acquired by this vertical linear hydrophone array fall in this band and rain noise in work due to heavy precipitation only. Power spectral density of noise is computed using Welch’s averaged modified periodogram method. The data is split into smaller segments, with a Hamming window with a 50% overlap and Fast Fourier Transform performed.

**Results**

The main noise source in the open sea during cyclone events is rain. JAL cyclone originated on 4th November 2010 in southern part of the Bay of Bengal and crossed north of Tamilnadu on 7th November 2010. During the JAL cyclone, heavy rain fall of 100 mm/hr and 205 mm/hr on 6th and 7th November 2010 respectively was observed by the Doppler Radar of IMD, Chennai (Fig.1a-b).

![SUB-SURFACE SYSTEM LOCATION AT CUDDALORE](Fig. 1a—Satellite imagery during the passage of JAL cyclone on 6th November 2010)
The underwater ambient noise measuring system (hydrophone array) was located at 185km from the low pressure center of JAL cyclone and it recorded the ambient noise during the cyclone event. Measurements of heavy rainfall noise during JAL cyclone is shown in the Fig.2.

It has been analysed that noise due to ruptured rain bubbles were recorded by the ambient noise measuring system. Specific time series of a ruptured rain bubble⁸ is shown in the Fig.2 (enlarged portion). Rain drops having diameter 2.2 mm to 3.5 mm produce noise by fragmentation. It was clearly observed from the power spectrum (shown in Figure 3) that the noise levels were varying from 78 dB to 58 dB in the band 7 kHz to 10 kHz. These variations resembled the bubble fragmentations⁹. The decrease in noise level indicates that the raindrops which are impacted on the sea surface are not equal in dimension. This is because of the heavy rough windy conditions during cyclone event scatter the rain drops resulting in non-uniformity collision¹⁰. Acoustic signatures from the ruptured bubbles were due to the surface tension of the bubbles¹¹. This surface tension depends on the drop size. During the cyclone event, heavy rain fall was observed causing large size of rain drops. The time series measurement of rain noise at rainfall rate 205mm/hr is shown in the Figure 2. It has been observed from the power spectrum (Figure 3) that the noise level at rainfall rate 100mm/hr is less than the noise level at 205mm/hr. Hence the ambient noise level increases with precipitation¹². At the time of JAL cyclone the possibility of anthropogenic noise and man-made noise were insignificant. Therefore, the noise field was absolutely due to rain, sourced by cyclone. The magnitude of acoustic pulse produced by rain drops depends on drop size, shape and impact velocity. It has been analysed from the Figure 2 that whenever the rain drop impinged on the sea surface, an acoustic pulse was transmitted⁸ to the hydrophone, which was acquired and stored by the data acquisition system.

The number of peaks in the time series could be caused by either the number of rain drops or due to the impaction of secondary drops, which are produced by the fragmentation of large drops. In the present case, the size of the secondary drops and the acoustic pulses produced by them were fairly less and hence neglected in this analysis. Hence, it is deduced that the peaks are due to the number of drops that impinge on the sea surface.
Further analysis on number of rain drops is carried out (Fig.4a-4b).

The raise in noise level intensity during JAL cyclone period can be clearly seen in the spectrogram (Figure 5a-5b). For a closer view and better understanding, PSD was shown only for 7-10 kHz and the same could be clearly seen by the colour intensity variations in spectrograms. The work\textsuperscript{11} indicates that studying rainfall noise in ocean is a tool for measuring bubble creation rates at the ocean surface, which leads to air-sea gas transfer for better understanding the global carbon cycle.

Conclusion
Ocean ambient noise due to heavy rainfall during JAL cyclone has been analysed in shallow waters off Cuddalore in Bay of Bengal. During the cyclone and storm conditions, ambient noise level was observed to have increased by 5-10dB from normal values in the band 7 kHz to 10 kHz. This study reveals that by continuous monitoring of ambient noise along with wind and rain fall, the effect of these parameters on noise field can be understood and the rain fall parameters such as number of drops, drop size and impact velocity can be determined\textsuperscript{13}. The frequency spectra that were generated by the rain noise were used to detect the rain fall.

Acknowledgement
The authors are grateful to Director, NIOT for his encouragement and support in carrying out this work and Indian Meteorological Department, Chennai for providing cyclone tracks and satellite imageries.

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